(Chem. Soc.)

A SYSTEM OF CHEMISTRY.

A
SYSTEM
OF
CHEMISTRY:

COMPREHENDING THE

HISTORY, THEORY, AND PRACTICE

OF THE

SCIENCE,

ACCORDING TO THE LATEST DISCOVERIES AND IMPROVEMENTS.

ILLUSTRATED WITH COPPERPLATES.

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HISTORY of CHEMISTRY.

1 Definition. CHEMISTRY may be defined, The ſtudy of ſuch phenomena or properties of bodies as are diſcovered by variouſly mixing them together, and by expoſing them to different degrees of heat, alone, or in mixture, with a view to the enlargement of our knowledge in nature, and to the improvement of the uſeful arts: or, It is the ſtudy of the effects of heat and mixture upon all bodies, whether natural or artificial, with a view to the improvement of arts and natural knowledge.

2 Antiquity. The ſcience of chemiſtry is undoubtedly of very high antiquity; and, like moſt other ſciences, its origin cannot be traced. In ſcripture, Tubal Cain, the 8th from Adam, is mentioned as the father or inſtructor of every artificer in braſs or iron. This, however, does not conſtitute him a chemiſt, any more than a founder or blackſmith among us has a right to that title. The name of chemiſt could only belong to him, whoever he was, who firſt diſcovered the method of extracting metals from their ores; and this perſon muſt neceſſarily have lived before Tubal Cain, as every blackſmith or founder muſt have metals ready prepared to his hand. Neverthelefs, as Tubal Cain lived before the flood, and the ſcience of chemiſtry muſt have exiſted before his time, ſome have conjectured, that the metallurgic part, on account of its extreme uſefulneſs to mankind, was revealed to Adam by God himſelf.

3 Science founded. Be this as it will, *Siphoas*, an Egyptian, is conſidered by the chemiſts as the founder of their ſcience. He was known by the Greeks under the name of *Hermes*, or *Mercurius Triſmegiſtus*; and is ſuppoſed to have lived more than 1900 years before the Chriſtian æra. A numerous liſt of this philoſopher's works is given by Clemens Alexandrinus; but none of them are now to be found, nor do any of them appear to have been written profeſſedly on chemiſtry.

Two illuſtrious Egyptians, of the name of Hermes, are recorded by ancient authors. The elder ſuppoſed to be the ſame with *Mizraim*, the grandſon of Noah, the *Hermes* of the Greeks, and *Mercury* of the Romans. The younger Hermes lived a thouſand years afterwards; and is ſuppoſed to have reſtored the ſciences after they had fallen into oblivion, in conſequence of an inundation of the Nile. No leſs than 36,000 books are ſaid to have been written under the name of Hermes; but, according to Jamblichus, a cuſtom prevailed of inſcribing all books of ſcience with the name of Hermes. Some authors deny the exiſtence of Hermes, and maintain that his hiſtory is allegorical. 4

As the ſcience of chemiſtry is ſuppoſed to have been well known to the Egyptians, Moſes, who was ſkilled in their wiſdom, is thence ranked among the number of chemiſts; a proof of whoſe ſkill in this ſcience is thought to be, his diſſolving the golden calf made by the Iſraelites, ſo as to render it potable. Moſes ſuppoſed to be ſkilled in chemiſtry.

Of all the Greeks who travelled into Egypt in order to acquire knowledge, Democritus alone was admitted into their myſteries. The Egyptian prieſts are ſaid to have taught him many chemical operations; among which were the arts of ſoftening ivory, of vitrifying flints, and of imitating precious ſtones. Dr Black, however, is of opinion, that Democritus knew nothing more of theſe arts than that of making a coarſe kind of glaſs, as no mention is particularly made of his imitating any other precious ſtone than the emerald, whoſe colour is green; and the coarſer the glaſs the greener it is.

After the time of Democritus, we may know that conſiderable improvements were made in chemiſtry, as phyſicians began to make uſe of metallic preparations, as ceruſe, verdegris, litharge, &c. Dioſcorides deſcribes the diſtillation of mercury from cinnabar by means of an *embic*, from which, by adding the Arabic *Al*, comes the term *Alembic*. The art of diſtillation, however, at that time was in a very rude ſtate; the operation being performed chiefly by ſeparating the air, and more ſubtle part of tar, from the reſt of the matter. This was done by putting the matter to be diſtilled into a veſſel, the mouth of which was covered with a wet cloth; and by this the ſteams of aſcending vapour were condenſed, which were afterwards procured by wringing out the cloth. No other diſtillation, beſides this kind, is mentioned by Galen, Oribaſius, Ælian, or Paulus Ægineta. 5 Derivation of the word Alembic. 6 Original method of diſtilling.

The preciſe time is not known when the three mineral acids were firſt diſcovered; though, as no mention is made of them by Geber, Avicenna, or Roger Bacon, it is probable that they were not known in the 12th century.

tary. Raymond Lully gives ſome hints of his being acquainted with the marine acid; whence it is probable, that it was diſcovered towards the end of the 13th, or beginning of the 14th century.

7
Pliny's account of the origin of glaſs-making.

Several chemical facts are related by Pliny, particularly the making of glaſs, which he aſcribes to the following accident. "Some merchants in the Levant, who had nitre on board their ſhip, having occaſion to land, lighted a fire on the ſand in order to prepare their food. To ſupport their veſſels they took ſome of the lumps of nitre with which their ſhip was loaded: and the fire acting on theſe, melted part of them along with the ſand, and thus formed the tranſparent ſubſtance called glaſs, to the great ſurpriſe of the beholders." But it is probable, that the art of glaſs-making was known long before; and it is by no means likely that it took its riſe from ſuch an accident.

8
Alchemy firſt mentioned by Firmicus Maternus.

The next traces we find of chemiſtry are to be extracted from the extravagant purſuits of the *Alchemiſts*, who imagined it poſſible to convert the baſer metals into gold or ſilver. The firſt mention we find of this ſtudy is by Julius Firmicus Maternus, who lived in the beginning of the fourth century, and ſpeaks of it as a well known purſuit in his time. Æneas Blaſius, who lived in the fifth century, likewiſe ſpeaks of it; and Suidas explains the term by telling us, that it is the art of making gold and ſilver. He tells us, that Diocleſian, when perſecuting the Chriſtians, forbad all chemical operations, leſt his ſubjects ſhould diſcover the art of making gold, and thus be induced to rebel againſt him.

9
Origin of the fable the Argonauts.

He ſuppoſes alſo, that the Argonautic expedition was only an attempt to procure a ſkin or parchment, on which was written the *recipe* for making gold. It is a common practice, however, in ſome places where gold is waſhed down in ſmall particles by brooks and rivulets from the mountains, to ſuſpend in the water the ſkins of animals having wool or hair upon them, in order to detain the heavier particles which contain the gold; and this probably gave riſe to the fable of the golden fleece. Suidas, however, who lived as late as the tenth century, deſerves very little credit, eſpecially as alchemy is not mentioned by any ancient author.—The Arabian phyſicians afford the moſt clear and diſtinct evidence concerning alchemy. Avicenna, who lived in the tenth century, is ſaid by a diſciple of his to have wrote upon alchemy; he mentions alſo roſe-water, and ſome other chemical preparations; and in the 12th century we find phyſicians adviſed to cultivate an acquaintance with the chemiſts; and another of the Arabian writers ſay, that the method of preparing roſe water, &c. was then well known.

10
Alchemy firſt ſuppoſed to be derived from the Arabians.

—From this evidence of the exiſtence of alchemy among the Arabians, with the prefatory article *Al*, to denote the greatneſs of the ſcience, it has been conjectured, that the doctrine of the tranſmutation of metals firſt took its riſe among the Arabians, and was introduced into Europe by means of the Cruſades, and by the rapid conqueſts of the Arabians themſelves in Europe as well as in Aſia and Africa. Europe at that time had been in a ſtate of the greateſt barbarity from the incurſions of the northern nations; but the Arabians contributed to revive ſome of the ſciences, and introduced alchemy among the reſt, which continued till the middle of the 17th century; at which time the extravagance of its profeſſors roſe to the greateſt height.

11
No credit due to the doctrine of tranſmutation.

Though the pretenſions of the alchemiſts are now univerſally refuted, yet from ſome of the diſcoveries which have been made in chemiſtry, we are even yet in danger of giving ſome credit to the poſſibility of the proceſs of tranſmutation. When we conſider that the metals are bodies compounded of parts which we can take away and reſtore, and that they are cloſely allied to one another in their external appearance, we may be inclined to think favourably even of the projects of the alchemiſts. The very ſeparation of the metals from their ores, the depriving them of their ductility and malleability, and the reſtoration of theſe properties to them at pleaſure, will appear very ſurpriſing to thoſe who are unacquainted with chemiſtry.

12
Quickſilver produced from lead.

There are alſo proceſſes of the more difficult kind, by which quickſilver may be produced from metals that are commonly ſolid, as from lead. Some of theſe we find in Boerhaave, Boyle, &c. authors of the greateſt credit, who both ſpeak of the operation and product as realities of which they were convinced by their own experience. Theſe have been urged, not without ſome plauſibility, in favour of the tranſmutation of the imperfect metals into gold; and hence the deluſions of alchemy were not confined to the vain, the ignorant, and the ambitious part of mankind; but many ingenious and learned men, who took pleaſure in the ſtudy of nature, have been ſeduced into this unhappy purſuit. This happened chiefly in Germany, where the variety of mines naturally turned the thoughts of chemiſts principally towards the metals, though the numerous failures of thoſe who had attempted this art ought to have taught them better.

About the beginning of the 16th century, the pretenders to alchemy were very numerous, and a multitude of knaves, who had beggared themſelves in the attempt, now went about to enſnare others, performing legerdemain tricks, and cauſing people believe that they could actually make gold and ſilver. A number of the tricks they made uſe of are to be met with in Lemery. Many books, with the ſame deſign of impoſing upon mankind, were written upon the ſubject of alchemy. They aſſumed fictitious names of the greateſt antiquity, and contained rules for preparing the philoſopher's ſtone; a ſmall quantity of which thrown into a baſe metal ſhould convert the whole into gold. They are wrote in a myſterious ſtyle, without any diſtinct meaning; and though ſometimes proceſſes are clearly enough deſcribed, they are found to be falſe and deceitful upon trial, the products not anſwering the pretenſions of the authors. Their excuſe was, that it was vain to expect plain accounts of theſe matters, or that the books on theſe ſubjects ſhould be written diſtinctly and clearly; that the value of gold was in proportion to its ſcarcity, and that it might be employed to bad purpoſes: they wrote only for the laborious and judicious chemiſts, who would underſtand them provided they made themſelves acquainted with the metals by ſtudy and experience. But in fact, no diſtinct meaning has ever been obtained, and the books have only ſerved to delude and betray a great number of others into the loſs of their *lives*.

But though the alchemiſts failed in the execution of their

13 Chemiſtry derived ſome advantages from the labours of the alchemiſts.

their grand project, we muſt ſtill own ourſelves indebted to them for many diſcoveries brought to light during the time they vainly ſpent their labour in the expectation of making gold. Some of theſe are the methods of preparing ſpirit of wine, aquafortis, volatile alkali, vitriolic acid, and gun-powder. Medicine too was indebted to them for ſeveral valuable remedies; whence alſo it appears that many, who had waſted their time in the vain purſuit of the philoſoper's ſtone, thought of trying ſome of their moſt elaborate preparations in the cure of diſeaſes; and meeting with ſome ſucceſs, they preſumed that diſeaſes were only to be cured by the aſſiſtance of chemiſtry; and that the moſt elaborate of all its preparations, the philoſopher's ſtone, would cure all diſeaſes. Some cures they performed did indeed awaken the atttention of phyſicians; and they introduced the uſe of opium, which had formerly been accounted poiſonous. They ſucceeded alſo in the cure of the venereal diſeaſe, which had lately made its appearance, and baffled the regular phyſicians; but the chemiſts, by giving mercury, put a ſtop to its ravages, and thus introduced this valuable article into the materia medica.

14 of Paracelſus.

The moſt famous of the chemical profeſſors was Paracelſus, well known for his arrogance, abſurdity, and profligacy. He was bred to the ſtudy of medicine; but becoming acquainted with the alchemiſts, travelled about in the character of a phyſician, and was at great pains to collect powerful medicines from all quarters. Theſe he uſed with great freedom and boldneſs. His ſucceſs in ſome caſes operated ſo upon the natural arrogance and ſelf-ſufficiency of his diſpoſition, that he formed a deſign of overturning the whole ſyſtem of medicine, and ſupplying a new one from chemiſtry: and indeed he found but very weak adverſaries in the ſubtle theories of Galen with the refinements of the Arabian phyſicians, which only prevailed in his time; and he no doubt had ſome ſhare in baniſhing that veneration which had been ſo long entertained for theſe celebrated perſonages.

15 Hiſtory of chemiſtry ſince the time of Paracelſus.

16 The ſcience ſtudied by Lord Verulam;

From the time of Paracelſus, chemiſtry began every where to aſſume a new face. In Great Britain, Lord Verulam amuſed himſelf at his leiſure hours with forming plans for promoting the ſciences in general, eſpecially thoſe which related to the ſtudy of nature. He ſoon found that chemiſtry might turn out one of the moſt uſeful and comprehenſive branches of natural philoſophy, and pointed out the means of its improvement. A number of experiments were propoſed by him; but he obſerved, that the views of chemiſts were as yet only adapted to explain their particular operations on metals; and he obſerved, that, inſtead of the abſtruſe and barren philoſophy of the times, it was neceſſary to make a very large collection of facts, and to compare them with each other very maturely and cautiouſly, in order to diſcover the common cauſes and circumſtances of connection upon which they all depend. He did not, however, make any conſiderable diſcoveries, and his works are tedious and diſagreeable to the reader.

17 And by Mr Boyle.

A ſuperior genius to Lord Verulam was Mr Boyle, who was born the very day that the former died. His circumſtances were opulent, his manners agreeable; he was endowed by nature with a goodneſs of heart; and his inclination led him entirely to the ſtudy of nature, which he was beſt pleaſed with cultivating in the way of experiment. He conſidered the weight, ſpring, and qualities of the air; and wrote on hydroſtatics and other ſubjects; and was poſſeſſed of that happy penetration and ingenuity ſo well ſuited to the making of experiments in philoſophy, which ſerves to deduce the moſt uſeful truths from the moſt ſimple and ſemingly inſignificant facts. As chemiſtry was his favourite ſcience, he ſpared no pains to procure from chemiſts of greateſt note the knowledge of curious experiments, and entertained a number of operators conſtantly about him. His diſcoveries are related in an eaſy ſtyle: and though rather copious, ſuited to the taſte of the times in which he lived, and free from that abſurd and myſterious air which formerly prevailed in chemical writings: nor does he betray a deſign of concealing any thing except ſome particulars which were communicated to him under the notion of ſecrecy, or the knowledge of which might do more harm than good. It is objected indeed, that he betrays a good deal of credulity with regard to facts which are given on the faith of others, and which may ſeem incredible; but this proceeded from his candour, and his being little diſpoſed to ſuſpect others. He ſhowed the neceſſary connection between philoſophy and the arts; and ſaid, that by attending the ſhop of a workman, he learned more philoſophy than he had done in the ſchools for a long time Thus his writings ſhowed an univerſal taſte for the ſtudy of nature, which had now made ſome advances in the other parts of the world.

18 Chemiſtry emerges from its obſcurity.

Agricola is one of the firſt and beſt authors on the ſubject of metallurgy. Being born in a village in Miſnia, a country abounding in mines and metallurgic works, he deſcribed them exactly and copiouſly. He was a phyſician, and cotemporary with Paracelſus, but of a character very different. His writings are clear and inſtructive, as thoſe of Paracelſus are obſcure and uſeleſs. Lazarus Erker, Schinder, Schlutter, Henkel, &c. have alſo written on metallurgy, and deſcribed the art of aſſaying metals. Anthony Neri, Dr Merret, and the famous Kunckel (who diſcovered the phoſphorus of urine), have deſcribed very fully the arts of making glaſs, enamels, imitations of precious ſtones, &c.: but their writings, as well as thoſe of ſucceeding chemiſts, are not free from the illuſions of alchemy; ſo true it is, that an obſtinate and inveterate malady never diſappears at once, without leaving traces behind. In a ſhort time, however, the alchemical phrenzy was attacked by many powerful antagoniſts, who contributed to reſcue the ſcience of chemiſtry from an evil, which at once diſgraced it and retarded its progreſs. Among theſe, the moſt diſtinguiſhed are Kircher a Jeſuit, and Conringius a phyſician, who wrote with much ſucceſs and reputation.

19 Royal Society how founded,

About the year 1650 the Royal Society was formed by a number of gentlemen who were unwilling to engage in the civil wars; and being ſtruck with the extenſive views of Lord Verulam and Mr Boyle, contributed to the expence of coſtly experiments. This example appeared ſo noble, and the deſign ſo good, that it has been followed by all the civilized ſtates of Europe, and has met with the protection of their reſpective ſovereigns; and from theſe chemiſtry has received conſiderable improvements. In France, Geoffroy, Lemery, Reaumur, &c. came to be diſtinguiſhed;

ed; and in Germany Margraaf, Pott, and others, have made a conſiderable figure in thoſe ſocieties. Kunckel, Begar, Stahl, and Hoffman, &c. have done great ſervice to ſociety, by introducing new arts, and the numerous improvements they have made.

20
Of the improvements made by different nations in chemiſtry.

The chemiſts who have made a figure in Germany and France are more in number than thoſe whom Britain has produced. In France, the ſociety was encouraged by the ſovereign; and in it they have diveſted themſelves of that myſterious air which was affected in former ages. In Germany, the richneſs of the country, and the great variety of mines, by turning the attention of chemiſts to the metals, have given that alchymiſtical air to their writings which we obſerve in them. The number of thoſe who have applied themſelves to chemiſtry is very ſmall in England, owing to the great improvements made by Sir Iſaac Newton in the ſciences of aſtronomy and optics; which, by turning the general attention that way, has occaſioned what may be called a neglect of chemiſtry. But if their number be inconſiderable, they are by no means inferior in merit and fame. The name of Boyle has always been held in the higheſt eſteem, as well as that of Hales, for the analyſis he has made of the air. Sir Iſaac Newton alone has done more to the eſtabliſhing a rational chemical theory than ever was done before. Of late, the taſte for the ſtudy has became more general, and many uſeful books have appeared; ſo that it is to be hoped they will ſoon excel in this branch of ſcience, as they have done in all the reſt.

THEORY

THEORY OF CHEMISTRY.

PART I.

21 Perfect Theory, what. ACCORDING to the definition we have given of this ſcience, the theory of it ought to conſiſt in a thorough knowledge of all the phenomena which reſult from every poſſible combination of its objects with one another, or from expoſing them in all poſſible ways to thoſe ſubſtances which chemiſts have found to be the moſt active in producing a change. So various, however, and ſo widely extended are the objects of chemiſtry (comprehending all terreſtrial bodies whatever), that a knowledge of this kind is utterly unattainable by man. The utmoſt that can be done in this caſe is, to give ſome account of the phenomena which accompany the mixtures of particular ſubſtances, or the appearances they put on when expoſed to heat; and theſe have been already ſo well aſcertained, that they may now be laid down as rules, whereby we may, with a good deal of certainty, judge of the event of our experiments, even before they are made.

22 Objects of Chemiſtry, what. Here we muſt obſerve, that though the objects of chemiſtry are as various as there are different ſubſtances in the whole ſyſtem of nature, yet they cannot all be examined with equal eaſe. Some of theſe ſubſtances act upon others with great violence; and the greater their activity, the more difficultly are they themſelves ſubjected to a chemical examination. Thus, fire, which is the moſt active body in nature, is ſo little the ſubject of examination, that it hath hitherto baffled the ingenuity of the greateſt philoſophers to underſtand its compoſition. This ſubſtance, therefore, though it be the principal, if not the only *agent* in chemiſtry, is not properly an *object* of it, becauſe it cannot be made a ſubject of any chemical operation.

23 Suppoſition of elements the origin of alchemy. It hath been cuſtomary to conſider all bodies as compoſed of certain permanent and unchangeable parts called *elements*; and that the end of chemiſtry was to reſolve bodies into theſe elements, and to recompoſe them again by a proper mixture of the elements when ſo ſeparated. Upon this ſuppoſition the alchemiſts went; who, ſuppoſing that all bodies were compoſed of ſalt, ſulphur, and mercury, endeavoured to find out the proportions in which theſe exiſted in gold, and then to form that metal by combining them in a ſimilar manner. Had they taken care to aſcertain the real exiſtence of their elements, and, by mixing them together, compoſed any one metal whatever, though but a grain of lead, the leaſt valuable of them all; their pretenſions would have been very rational and well founded; but as they never aſcertained the exiſtence of ſuch elementary bodies, it is no wonder that their labours were never attended with ſucceſs.

Another ſet of elements which were as generally received, and indeed continue to be ſo in ſome meaſure to this day, are fire, air, earth, and water.—This doctrine of elements was ſtrenuouſly oppoſed by Mr Boyle; who endeavoured to prove, that fire was not an element *per ſe*, but generated merely from the motion of the particles of terreſtrial bodies among one another; that air was generally produced from the ſubſtance of ſolid bodies; and that water, by a great number of diſtillations, was converted into earth. His arguments, however, concerning fire were not at all concluſive; nor does the expulſion of air from fixed bodies prove that any of their ſolid parts were employed in the compoſition of that air; as later diſcoveries have ſhown that air may be abſorbed from the external atmoſphere, and fixed in a great number of ſolid ſubſtances. His aſſertion concerning water deſerves much conſideration, and the experiment is well worth repeating; but it does not appear that he, or any other perſon, ought to have relied upon the experiment which was intended to prove this tranſmutation. The fact was this. Having deſigned to try the poſſibility of reducing water to earth by repeated diſtillations, he diſtilled an ounce of water three times over himſelf, and found a ſmall quantity of earth always remaining. He then gave it to another, who diſtilled it 197 times. The amount of earth from the whole diſtillations was ſix drams, or $\frac{3}{4}$ths of the quantity of water employed; and this earth was fixed, white, and inſoluble in water.—Here it is evident, that great ſuſpicions muſt lie againſt the fidelity of the unknown operator, who no doubt would be wearied out with ſuch a number of diſtillations. The affair might appear trivial to him; and as he would perhaps know to which ſide Mr Boyle's opinion inclined, he might favour it, by mixing ſome white earth with the water. Had the experiment been tried by Mr Boyle's own hand, his known character would have put the matter beyond a doubt. 24 Mr Boyle's opinion.

The decompoſition of water, however, in another way, by the combination of one part of it with the

phlogistic, and another with the earthy part of a metal, is now well ascertained, and the experiments which led to the discovery are treated of under the articles AEROLOGY and WATER.

25 Existence of elements disputed.

Even the existence of earth as an element appears as dubious as that of the others; for it is certain that there is no species of earth whatever, from which we can produce two dissimilar bodies, by adding their other component parts.—Thus, the earth of alum has all the characters of simplicity which we can desire in any terrestrial substance. It is white, insipid, inodorous, and perfectly fixed in the fire; nevertheless, it seems to be only an element of that particular body called *alum*; for though alum is composed of a pure earth and vitriolic acid joined together, and Epsom salt and selenite are both composed of a pure earth combined with the same acid; yet by adding oil of vitriol to the earth of alum, in any possible way, we shall never be able to form either Epsom salt or selenite. In like manner, though all the imperfect metals are composed of inflammable matter joined with an earthy basis; yet by adding to earth of alum any proportion we please of inflammable matter, we shall never produce a metal; and what is still more mortifying, we can never make the earthy basis of one metallic substance produce any other metal than that which it originally composed.

26 Elements necessarily invisible.

A little consideration upon the subject of elements will convince us, not only that no such bodies have ever yet been discovered, but that they never will; and for this plain reason, that they must be in their own nature invisible.—The component parts of any substance may with propriety enough be called the elements of that substance, as long as we propose carrying the decomposition no farther; but these elements have not the least property resembling any substance which they compose. Thus, it is found that the compound salt called *sal ammoniac*, is formed by the union of an acid and an alkali: we may therefore properly enough call these two the elements of sal ammoniac; but, taken separately, they have not the least resemblance to the compound, which is formed out of them. Both the acid and alkali are by themselves so volatile as to be capable of dissipation into an invisible vapour by the heat of one's hand; whereas, when joined together, they are so fixed as almost to endure a red heat without going off. If, again, we were to seek for the elements of the acid and alkali, we must not expect to find them have any properties resembling either an acid or an alkali, but others quite different. Any common element of all bodies must therefore be a substance which has no property similar to any other in the whole system of nature, and consequently must be imperceptible.

27 Supposition concerning phlogiston.

To the abovementioned four elements, viz. fire, air, earth, and water, a kind of *fifth* element has generally been added, but not usually distinguished by that name, though it has apparently an equal, if not a greater, right to the title of an *element* than any of the others. This substance is called the *phlogiston*, or inflammable principle; on which the ignition of all bodies depends. The existence of this element was first asserted by Stahl, and from him the opinion has been derived to other chemists: but of late a new doctrine was broached by M. Lavoisier, who denies the existence of phlogiston altogether. Though none of these substances therefore are properly the objects of chemistry, yet as they have so much ingrossed the attention of modern chemists, we shall here give an account of the most remarkable theories that have appeared concerning them.

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SECT. I. *Of the Element of Fire.*

28 Two general theories of heat.

THE opinions concerning the element of fire may be divided into two general classes; the one considering it as an effect, the other as a cause. The former is maintained by Lord Bacon, Mr Boyle, and Sir Isaac Newton; whose respectable names for a long time gave such a sanction to this theory, that it was generally looked upon as an established truth. Some learned men, however, among whom was the great Dr Boerhaave, always dissented, and insisted that fire was a fluid universally diffused, and equally present in the frozen regions of Nova Zembla as in a glass-house furnace, only that in the latter its motion made it conspicuous; and by setting it in motion in the coldest parts of the world, its previous existence there would be equally demonstrable as in the furnace abovementioned.

29 Lord Bacon's definition of heat.

Lord Bacon defines heat, which he uses as a synonymous term with fire, to be an expansive undulatory motion in the particles of a body, whereby they tend with some rapidity towards the circumference, and also a little upwards. Hence, if in any natural body you can excite a motion whereby it shall expand or dilate itself, and can repress and direct this motion upon itself in such a manner that the motion shall not proceed uniformly, but obtain in some parts and be checked in others, you will generate heat or fire.

30 Mr Boyle's opinion

The same opinion is supported by Mr Boyle in the following manner: "The production of heat discovers nothing, either in the agent or patient, but motion, and its natural effects. When a smith briskly hammers a small piece of iron, the metal thereby becomes exceedingly hot: yet there is nothing to make it so, except the motion of the hammer impressing a vehement and variously determined agitation on the small parts of the iron; which, being a cold body before, grows hot by that superinduced motion of its small parts: first, in a more loose acceptation of the word, with regard to some other bodies, in comparison of which it was cold before; then sensibly hot, because the motion in the parts of the iron is greater than that in the parts of our fingers; at the same time that the hammer and anvil, by which the percussion is communicated, may, on account of their magnitude, remain cold. It is not necessary, therefore, that a body should itself be hot in order to communicate heat to another."

31 Sentiments of Sir Isaac Newton.

The arguments made use of by Sir Isaac Newton are not intended positively to establish any kind of theory relating to fire, but are to be found in a conjecture, published at the end of his Treatise on Optics, concerning the nature of the sun and stars. "Large bodies (he observes) preserve their heat the longest, their parts heating one another; and why may not great, dense, and fixed bodies, when heated beyond a certain degree, emit light so copiously, as, by the emission and reaction of it, and the reflections and refractions within the pores, to grow continually hotter, till they arrive at such a period of heat as is that of the sun? Their parts

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parts may be further preserved from fuming away, not only by their fixity, but by the vast weight and density of the atmosphere incumbent on them, strongly compressing them, and condensing the vapours exhaled from them. Thus we see, that warm water, in an exhausted receiver, shall boil as vehemently as the hottest water exposed to the air: the weight of the incumbent atmosphere in this latter case keeping down the vapours, and hindering the ebullition till it has received its utmost degree of heat. Thus also a mixture of tin and lead, put on a red hot iron *in vacuo*, emits a fume and flame: but the same mixture in the open air, by reason of the incumbent atmosphere, does not emit the least sensible flame." In consequence of these experiments, Sir Isaac conjectures, that there is no essential distinction betwixt fire and gross bodies; but that they may be converted into one another. "Fire (he says) is a body heated so hot as to emit light copiously; for what (says he) is a red hot iron but fire?"

32 Fire now generally allowed to be an element *per se*.

The hypotheses of these great men produced long and violent disputes, which were never decisively settled: The discoveries in electricity, however furnished such additional strength to the followers of Dr Boerhaave, that fire is now believed to be an element and fluid distinct from all others, by at least as many as espouse the contrary system; but the question is not decided, Whether the fire itself is to be considered as the agent? or, Whether its action is to be derived from the principles of attraction and repulsion, the natural agents supposed to influence other material substances? This has produced two other systems of a kind of mixed nature, in which heat or fire is considered as a substance distinct from all others, but which acts in other bodies according to its *quantity*. These systems have been promulgated by Dr Black of Edinburgh and Dr Irvine of Glasgow.

33 Two other theories instituted.

34 In what they differ from the former.

They differ from the opinions of Mr Boyle, Lord Bacon, and Sir Isaac Newton, in supposing heat to be a fluid distinct from all other material substances; and they also differ from the hypothesis of Dr Boerhaave, Lemery, and others, in supposing different terrestrial substances to be hot according to the *quantity* of fluid contained, and not according to the force with which it moves in them.

35 General account of Dr Black's and Dr Irvine's theories.

Dr Black is of opinion that *heat*, which he seems to make synonymous with fire, exists in two different states; in one of which it affects our senses and the thermometer, in the other it does not. The former therefore he calls *sensible* heat, the later *latent* heat. On these principles he gives the only satisfactory explanation of the phenomena of evaporation and fluidity that has yet appeared, as shall afterwards be more fully explained. At present we shall only observe, that, according to the theory of Dr Black, heat or fire itself seems to be the agent; but, according to that of Dr Irvine, as far as we can gather it from the treatises of Dr Crawford and others, the principles of attraction and repulsion are the agents by which heat, as well as other bodies, is influenced. Thus, on the principles of Dr Black, we say, that water is converted into vapour by a quantity of heat entering into it in a *latent* state, and thereby rendering it specifically lighter than the atmosphere; according to the principles of Dr Irvine, we say, that water is converted into vapour by having its capacity for attracting heat from the atmosphere increased. So that, according to the former, the absorption of heat is the *cause*; according to the latter, the *effect*, of its conversion into vapour.

36 Dr Irvine's theory explained by Dr Crawford.

Dr Crawford, in his Treatise on Heat, published in 1788, informs us, that *heat*, in the philosophical sense of the word, has been used to express what is frequently called the *element of fire*, in the abstract, without regard to the peculiar effects which it may produce in relation to other bodies.

37 Absolute heat defined.

This, with Dr Irvine, he calls *absolute* heat; and the external cause, as having a relation to the effects it produces, he calls *relative* heat. "From this view of the matter (says he), it appears, that *absolute heat* expresses, in the abstract, that *power* or *element* which, when it is present to a *certain* degree, excites in all animals the sensation of heat; and *relative* heat expresses the same power, considered as having a relation to the effects by which it is known and measured.

83 Relative heat,

39 How divided.

"The effects by which heat is known and measured are three; and therefore relative heat may admit of three subdivisions. 1. This principle is known by the peculiar sensations which it excites in animals. Considered as exciting those sensations, it is called *sensible* heat. 2. It is known by the effect which it produces upon an instrument that has been employed to measure it, termed a *thermometer*. This is called the *temperature of heat in bodies*. 3. It has been found by experiment, that in bodies of different kinds the quantities of absolute heat may be unequal, though the temperatures and weights be the same. When the principle of heat is considered relatively to the whole quantity of it contained in bodies of different kinds, but which have equal weights and temperatures, I shall term it *comparative heat*. If, for example, the temperatures and weights being the same, the whole quantity of heat in water be four times as great as that of antimony, the comparative heats of these substances are said to be as four to one."

40 Comparative heat defined.

41 Experiments by which Dr Black was led to the discovery of latent heat.

In order to have a proper conception of what is meant by a difference in absolute heat, when the temperatures are the same, it will be necessary to relate some experiments, by which Dr Black was first led to the discovery of latent heat. He observes, that when two equal masses of the same matter, heated to different degrees, are mixed together, the heat of the mixture ought to be an arithmetical mean betwixt the two extremes. This, however, only takes place on mixing hot and cold water together; but if instead of cold water we take ice, the case is remarkably different.

42 A quantity of heat lost in the melting of ice.

Here the temperature of the mixture is much below the arthmetical mean, and a quantity of heat is apparently lost. Now we know that the temperature of ice newly frozen is generally 32 degrees of Fahrenheit; supposing therefore the temperature of the water which dissolves it to be 120, the arithmetical mean is 71; but if the mixture indicates a temperature only of 60°, then we must suppose that the ice contained 11° of heat less than was indicated by the thermometer; and consequently, that water at 32° contains 11° more of absolute heat than ice at 32°.

43 Great quantity of heat produced by the condensation of vapour.

The same thing is made still more evident from the condensation of vapour. The fluid of water is not capable of sustaining a great degree of heat; and 212° of Fahrenheit is the utmost it can be made to bear, without an extraordinary degree of pressure, as in Papin's

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pin's digester, or the admixture of saline substances: the temperature of the steam emitted by it therefore never can exceed 212°, except in the cases just mentioned; and it is often capable of bearing a great degree of cold without being condensed. When the condensation takes place at last, however, a very considerable degree of heat is always produced; and Dr Black has shown, that, in the condensation of steam by the refrigeratory of a common still, as much heat is communicated to the water in the refrigeratory as would be sufficient to make the water which comes over as hot as red hot-iron, were it all to exist in a sensible state. His method of making the calculation is very easy. For, supposing the refrigeratory to contain 100 pounds of water, and that one pound has been distilled; if the water in the refrigeratory has received 10 degrees of heat, we know that the distilled pound has parted with 1000. If in passing through the worm of the refrigeratory, it has been reduced to the temperature of 50° of Fahrenheit, having been at 212° when it entered it, then it has lost only 162° of sensible heat; all the rest communicated to the water of the refrigeratory amounting to more than 800°, having been contained in a latent state, and such as could not then affect the thermometer. This experiment was tried by Mr Watt in a manner still more striking, by a distillation of water *in vacuo*. Thus the steam, freed from the pressure of the atmosphere, could not conceive such a degree of sensible heat as in the common method of distilling. It came over therefore with a very gentle warmth, scarce more than what the hand could bear; nevertheless it had absorbed as much heat as though the distillation had been performed in the common way; for the refrigeratory had 1000 degrees of heat communicated to it.

44 Dr Black's method of calculating it.

45 Mr Watt's experiment on the distillation of water *in vacuo*

46 Difference of absolute heat in different fluids.

The difference of absolute heat is likewise perceptible betwixt any two bodies of different density, water and mercury for instance: and in comparing these, it will always be found that the thinnest fluids contain the greatest quantity of absolute heat; as water more than mercury, spirit of wine, more than water, ether more than spirit of wine, and air more than any of them. Dr Black having brought equal bulks of mercury and water, the former to a temperature of 50 degrees higher than the latter, found that, on mixture, there was a gain of only 20 degrees above the original; but on reversing the experiment, and heating the water 50 degrees above the mercury, there was a gain of 30 degrees on the whole. "Hence (says Dr Cleghorn in his thesis *de Igne*) it appears, that the quantity of heat in water is to that in mercury, when both are of equal temperatures, as 3 to 2." Dr Crawford, however, tells us, that "the same quantity of heat which raises a pound of water one degree, will raise a pound of mercury 28 degrees; whence it follows, that the comparative heat of water is to that of mercury as 28 to 1: and consequently, the alterations which are produced in the temperatures of bodies by given quantities of absolute heat, may properly be applied as a measure of their comparative heats; the alterations of temperature and the comparative heats being reciprocally proportional to one another.

47 Thinnest fluids contain the greatest quantity of heat.

48 Great difference betwixt the calculations of Drs Cleghorn and Crawford.

49 Crawford's account of sensible heat.

"Sensible heat (continues Dr Crawford) depends partly on the state of the temperature, and partly on that of the organ of feeling; and therefore if a variation be produced in the latter, the sensible heat will be different, though the temperature continue the same. Thus water at the temperature of 62° of Fahrenheit appears cold to a warm hand immersed in it; but on the contrary, that fluid will appear warm if a hand be applied to it which has a lower degree of heat than 62°. For this reason, the thermometer is a much more accurate measure of heat than the senses of animals. As long, however, as the organs remain unchanged, the sensible heat is in proportion to the temperature; and therefore those terms have generally been considered as synonymous. On this subject Dr Reid observes, that until the ratio between one temperature and another be ascertained by experiment and induction, we ought to consider temperature as a measure which admits of degrees, but not of ratios; and consequently ought not to conclude, that the temperature of one body is double or triple to that of another, unless the ratio of different temperatures were determined. Nor ought we to use the expressions of a *double* or *triple* temperature, those being expressions which convey no distinct meaning until the ratio of different temperatures be determined."

50 Dr Reid's observation concerning temperatures.

51 Difference betwixt the calculations of Drs Crawford and Black.

In making experiments on the comparative quantities of heat in different bodies, our author chooses rather to use equal *weights* than equal *bulks* of the substances to be compared. Thus he found the comparative heat of water to be to that of mercury as 28 to 1 by weight, and 2 to 1 by bulk; which differs very considerably from the conclusion of Dr Black, who makes it only as 3 to 2, as has been already mentioned.

52 Capacities for containing heat explained.

From the differences observed in the quantities of absolute heat contained in different bodies, our author concludes, that "there must be certain essential differences in the nature of bodies; in consequence of which, *some* have the power of collecting and retaining that element in greater quantity than *others*." These different powers he calls the *capacities* for containing heat. Thus, if we find by experiment that a pound of water contains four times as much absolute heat as diaphoretic antimony, when at the same temperature, the capacity of water for containing heat is said to be to that of animony as 4 to 1.

53 How the capacity, temperature, and absolute heat, are to be distinguished.

"The temperature, the capacity for containing heat, and the absolute heat contained, may be distinguished from each other in the following manner.

"The capacity for containing heat, and the absolute heat contained, are distinguished as a force distinct from the subject upon which it operates. When we speak of the capacity, we mean a power inherent in the heated body; when we speak of the absolute heat, we mean an unknown principle which is retained in the body by the operation of this power; and when we speak of the temperature, we consider the unknown principle as producing certain effects upon the thermometer.

"The capacity for containing heat may continue unchanged, while the absolute heat is varied without end. If a pound of ice, for example, be supposed to retain its solid form, the quantity of its absolute heat will be altered by every increase or diminution of its sensible heat: but as long as its form continues the same, its capacity for receiving heat is not affected by an

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an alteration of temperature, and would remain unchanged though the body were wholly deprived of its heat."

54 Crawford's opinion concerning heat in the abstract.

In the course of his work, Dr Crawford observes, that "he has not entered into the inquiry which has been so much agitated among the English, the French, and the German philosophers, Whether heat be a *substance* or a *quality*? In some places indeed he has used expressions which seem to favour the former opinion; but his sole motive for adopting these was, because the language seemed to be more simple and natural, and more consonant to the facts which had been established by experiment. At the same time, he is persuaded that it would be a very difficult matter to reconcile many of the phenomena with the supposition that heat is a *quality*. It is not easy to conceive, upon this hypothesis, how heat can be absorbed in the processes of fusion, evaporation, combustion; how the quantity of heat in the air can be diminished, and that in the blood increased, by respiration, though no sensible heat or cold be produced.

"Whereas, if we adopt the opinion that heat is a distinct substance, or an element *sui generis*, the phenomena will be found to admit of a simple and obvious interpretation.

55 Fire contained in bodies partly by its attraction to them, and partly by the pressure of the external fluid.

"Fire will be considered as a principle; which is distributed in various proportions throughout the different kingdoms of nature. The mode of its union with bodies will resemble that particular species of union, wherein the elements are combined by the joint forces of pressure and attraction. Of this kind is the combination of fixed air and water; for fixed air is retained in water partly by its attraction for that fluid, and partly by the pressure of the external air; and if either of these forces be diminished, a portion of the fixed air escapes. In like manner, it may be conceived that elementary fire is retained in bodies, partly by its attraction to these bodies, and partly by the action of the surrounding heat; and in that case a portion of it will be disengaged, either by diminishing the attractive force, or by lessening the temperature of the circumambient medium. If, however, fire be a substance which is subject to the laws of attraction, the mode of its union with bodies seems to be different from that which takes place in chemical combination: for, in chemical combination, the elements acquire new properties, and either wholly or in part lose those by which they were formerly characterized. But we have no sufficient evidence for believing that fire, in consequence of its union with bodies, does, in any instance, lose its distinguishing properties."

56 Dr Berkenhout's opinion concerning the nature of heat.

Dr Berkenhout, in his first Lines of the Theory and Practice of Philosophical Chemistry, informs us, that "heat, or the *matter of heat*, is by Scheele and Bergman substituted for fire, which they believe to be the action of heat when increased to a certain degree. The first of these celebrated chemists believed this *matter of heat* to be a compound of phlogiston and pure air. He was certainly mistaken. It seems more philosophical to consider heat as an *effect*, of which fire is the sole cause.

57 His division of fire into fixed and volatile.

"Heat I consider not as a distinct substance, but as an effect of fire, fixed or volatile; in both which states fire seems to exist in all bodies, solid and fluid. Fixed fire I believe to be a constituent part of all bodies, and their specific heat to depend on the quantity of fixed fire in each. This fixed, this latent fire, cannot be separated from the other constituent parts of bodies but by their decomposition: it then becomes volatile and incoercible. If this hypothesis be true, fire exists, in all natural bodies that contain phlogiston, in three different states: 1. In that volatile state in which it perpetually fluctuates between one body and another. 2. Combined with an acid, probably in the form of fixed inflammable air or phlogiston. 3. Uncombined and fixed, as a constituent principle, determining the specific heat of bodies.

58 Pure or volatile fire defined.

"Pure (or volatile) fire is distinguished by the following properties. 1. It is essentially fluid, invisible, and without weight. 2. It is the immediate cause of all fluidity. 3. It penetrates and pervades all bodies on the surface of the earth, and as far beneath the surface as hath hitherto been explored. Water hath never been found in a congealed state in the deepest mines. 4. It has a constant tendency to diffuse itself equally through all bodies, howsoever different in point of density. A marble slab, a plate of iron, a decanter of water, and a lady's muff, at the same distance from the fire, and other external circumstances, being equal, possess an equal degree of heat, which is precisely that of the atmosphere in which they stand. 5. It is perpetually in motion from one body to another, and from different parts of the same body, because external circumstances are continually varying. 6. In fluctuating from one body to another, it produces a constant vibration of their constituent parts; for all bodies expand and contract in proportion to the quantity of fire they contain. 7. Accumulated beyond a certain quantity, it effects the dissolution of bodies, by forcing their constituent parts beyond the sphere of mutual attraction, called the *attraction of cohesion*, which is the cause of solidity. Hence the sovereign agency of fire in chemical operations."

59 Dr Crawford's definition of fire.

Dr Crawford, besides the opinions already quoted, tells us, that fire, in the vulgar acceptation of the word, expresses a certain degree of heat accompanied with light; and is particularly applied to that heat and light which are produced by the inflammation of combustible bodies. But as heat, when accumulated in a sufficient quantity, is constantly accompanied with light; or, in other words, as fire is always produced by the increase of heat, philosophers have generally considered these phenomena as proceeding from the same cause: and have therefore used the word *fire* to express that unknown principle, which, when it is present to a certain degree, excites the sensation of heat alone; but, when accumulated to a greater degree, renders itself obvious both to the sight and touch, or produces heat accompanied with light. In this sense, the element of fire signifies the same thing with *absolute heat*.

Having premised these general definitions and remarks, he gives the properties of heat in the following words:

60 Heat has a tendency to diffuse itself equally over bodies.

"I. Heat has a constant tendency to diffuse itself over all bodies till they are brought to the same temperature. Thus it is found by the thermometer, that if two bodies of different temperatures are mixed together, or placed contiguous, the heat passes from the one to the other till their temperatures become equal; and

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and that all inanimate bodies, when heated and placed in a cold medium, continually lose heat, till in process of time they are brought to the state of the surrounding medium.

"From this property of heat it follows, that the various classes of bodies throughout the earth, if they were not acted upon by external causes, would at length, arrive at a common temperature when the heat would become quiescent; in like manner as the waters of the ocean, if not prevented by the winds and by the attractions of the sun and moon, would come to an equilibrium, and would remain in a state of rest. But as causes continually occur in nature to disturb the balance of heat as well as that of the waters of the ocean, those elements are kept in a constant fluctuation.

61 It is contained in considerable quantity in all bodies.

"II. Heat is contained in considerable quantities in all bodies when at the common temperature of the atmosphere.

62 Great degree of cold at Glasgow,

"From the interesting experiments which were made on cold by Mr Wilson, we learn, that at Glasgow, in the winter of the year 1780, the thermometer on the surface of snow sunk 25 degrees below the beginning of Fahrenheit's scale.

63 In Siberia, and at Hudson's bay.

"We are told by Dr Pallas, that in the deserts of Siberia, during a very intense frost, the mercury was found congealed in thermometers exposed to the atmosphere, and a quantity of that fluid in an open bowl placed in a similar situation, at the same time became solid. The decisive experiments of Mr Hutchins at Hudson's Bay prove, that the freezing point of mercury is very nearly 40° below the *zero* (or 0°) of Fahrenheit. From which it follows, that at the time of Dr Pallas's observation, the atmosphere in Siberia must have been cooled to minus 40. By a paper lately transmitted to the Royal Society we are informed, that the spirit-of-wine thermometer in the open air at Hudson's Bay fell to — 42 in the winter of 1785; and from the same communication we learn, that by a mixture of snow and vitriolic acid, the heat was so much diminished, that the spirit of wine sunk to — 80, which is 112 below the freezing point of water.

64 Quantity of heat limited in all bodies.

"Hence it is manifest, that heat is contained in considerable quantities in all bodies when at the common temperature of the atmosphere. It is plain, however, that the quantity inherent in each individual body is limited. This, I think, must be admitted, whatever be the hypothesis which we adopt concerning the nature of heat; whether we conceive it to be a force or power belonging to bodies, or an elementary principle contained in them. For those who consider heat as an element, will not suppose that an unlimited quantity of it can be contained in a finite body; and if heat be considered as a force or power, the supposition that finite bodies are actuated by forces or powers which are infinite is equally inadmissible.

65 Bodies universally expanded by heat.

"To place this in another light, we know that bodies are universally expanded by heat, excepting in a very few instances, which do not afford a just objection to the general fact; because, in those instances, by the action of heat a fluid is extricated that previously separated the particles from each other. Since, therefore, heat is found to expand bodies in the temperatures which fall within the reach of our observation, we may conclude that the same thing takes place in all temperatures."

66 Expansion of mercury, &c. proportionable to the degrees of heat.

Our author, by a set of very accurate and laborious experiments, determines that the expansions in mercury and some other fluids are proportionable to the quantities of heat applied; "from which (says he) it is manifest, that the quantities of heat in bodies are limited, because an infinite heat would produce an infinite expansion.

"It is manifest, that the number of degrees of sensible heat, as measured by the thermometer, and estimated from the beginning of the scale, must be the same in all bodies which have a common temperature; for by the first general fact it is proved, that heat has a constant tendency to diffuse itself uniformly over bodies till their temperatures become equal. From which it may be inferred, that if a quantity of heat were added to bodies absolutely cold, the same uniform diffusion would take place; and that if a thermometer, altogether deprived of its heat, were applied to such bodies, it would be equally expanded by them, the whole of the sensible heat which they had acquired being indicated by that expansion.

67 Homogeneous bodies of the same temperature, contain quantities of heat proportionable to those of their matter.

"III. If the parts of the same homogeneous substance have a common temperature, the quantity of absolute heat will be proportional to the bulk or quantity of matter. Thus the quantity of absolute heat in two pounds of water is double that which is contained in one pound when at the same temperature.

"IV. The dilatations and contractions of the fluid in the mercurial thermometer are nearly proportional to the quantities of absolute heat which are communicated to the same homogeneous bodies, or separated from them, as long as they retain the same form. Thus the quantity of heat required to raise a body four degrees in temperature by the mercurial thermometer, is nearly double that which is required to raise it two degrees, four times that required to raise it one degree, and so in proportion."

68 Mr Kirwan's opinion concerning fire.

Thus we find, that Dr Black, Dr Irvine, Dr Crawford, and Dr Berkenhout, agree in speaking of fire or heat as a fluid substance distinct from all other bodies. Mr Kirwan, in his Treatise of Phlogiston, agrees in the same opinion. "Some (says he) have thought, that I should have included the matter of heat, or elementary fire, in the definition of inflammable air; but as fire is contained in all corporeal substances, to mention it is perfectly needless, except where bodies differ from each other in the quantity of it they contain."

69 Mr Cavendish's opinion that it is not a distinct substance.

On the other hand, Mr Cavendish, Phil. Transf. lxxiv. P. 141. tells us, that "he thinks it more likely that there is no such thing as elementary heat:" but, as he gives no reason for this opinion, it seems probable that the greater part of philosophers either positively believe that heat is an elementary fluid distinct from all others, or find themselves obliged to adopt a language which necessarily implies it.

70 Difficulty in defining the phrase *quantity of heat*.

The only difficulty which now remains therefore is, to affix a proper idea to the phrase *quantity of heat*, which we find universally made use of, without any thing to determine our opinions concerning it.

71 This phrase cannot be used in the common acceptation of the word with regard to fire.

That we cannot speak of a *quantity* of fire or heat in the same sense as we speak of a quantity of water or any other fluid is evident, because we can take away the quantity of water which any substance contains, but cannot do so with heat. Nay, in many cases we are sure, that a substance very cold to the touch does yet

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yet contain a very conſiderable quantity of heat. The vapour of water, for inſtance, may be made much colder than the uſual temperature of the atmoſphere without being condenſed, when at the ſame time we are certain that it contains a great quantity of heat; and the ſame may be ſaid of water, which, in the act of freezing, throws out a great quantity of heat without becoming colder; and in the act of melting abſorbs as much without becoming warmer. It is not therefore by the mere preſence or abſence of this fluid that we can determine the real quantity of this fluid; nor does it appear that the word *quantity* can be at all accurately applied to the element itſelf, becauſe we have no method of meaſuring it.

72 Dr Cleghorn's opinion.

Dr Cleghorn, in his inaugural diſſertation *De Igne* throws ſome light on this ſubject, by obſerving, that "the thermometer ſhows only the quantity of heat *going out* of a body, not that which is really contained in it:" and he alſo inſiſts, that "we can neither aſſent to the opinion of Dr Boerhaave, who ſuppoſed that heat was diſtributed among bodies in proportion to their bulks; nor to the hypotheſis of others, who imagined that they were heated in proportion to their denſities." But in what proportion, then, are they heated; or how are we to meaſure the *quantity* which they really contain, ſeeing the thermometer informs us only of what they part with?

73 The latent heat of bodies cannot be meaſured.

As this point is by no means aſcertained, we cannot form a direct idea concerning the abſolute quantity of heat contained in any body; and therefore when we ſpeak of quantities of this fluid, we muſt in fact, if we mean any thing, think of the ſenſible quantity flowing out of them; and though we ſhould ſuppoſe the whole of this ſenſible heat to be removed, it would ſtill be impoſſible for us to know how much remained in a latent ſtate, and could not be diſſipated. This difficulty

74 Dr Cleghorn's hypotheſis concerning fire.

will ſtill appear the greater, if with Dr Cleghorn and others we ſuppoſe the fluid of heat to be ſubject to the laws of attraction and repulſion. This gentleman ſuppoſes, that the particles of heat (like the particles of electric fluid according to the Franklinian hypotheſis) are repulſive of one another, but attracted by all other ſubſtances. "If any body (ſays he), heated beyond the common temperature of the air, is expoſed to it, the heat flows out from it into the atmoſphere, and diffuſes itſelf equally all around till the air becomes of the ſame temperature with itſelf. The ſame happens to bodies ſuſpended *in vacuo*. Hence it is juſtly concluded, that there exiſts between the particles of heat a repulſive power, by which they mutually recede from each other. Notwithſtanding this repulſive power, however, the quantities of heat contained in different ſubſtances, even of the ſame temperature, are found to be altogether different; and from Dr Black's experiments it now appears, that the quantity of heat is ſcarce ever the ſame in any two different bodies: and hence we may conclude, that terreſtrial bodies have a power of attracting heat, and that this power is different in different ſubſtances.—From theſe principles it evidently follows, that heat is diſtributed among bodies directly in proportion to their attracting powers, and

75 Equilibrium of heat defined.

inverſely according to the repulſive power between the particles of heat themſelves. Such is the diſtribution of heat among bodies in the neighbourhood of each other; and which is called the *equilibrium of heat*, becauſe the thermometer ſhows no difference of temperature among them. For ſeeing the heat is diſtributed according to the attracting power of each, the thermometer having alſo a proper attraction of its own, can ſhow no difference in the attracting power of each; for which reaſon all bodies in the neighbourhood of each other are ſoon reduced to the ſame temperature."

76 The quantity of heat cannot be determind by this hypotheſis.

If we aſſent to Dr Cleghorn's hypotheſis, the quantity of heat contained in any ſubſtance depends, in the firſt place, on the attracting power of that ſubſtance, which is altogether unknown; and, in the ſecond place, on the repulſive powers of the particles of heat themſelves, which are equally unknown. To determine the *quantity*, therefore, muſt be impoſſible. Neither will the mixture of two different fluids, as in Dr Black's experiments, aſſiſt us in the leaſt; for though water, heated more than mercury, communicates a greater heat to that fluid than the latter does to water; this only ſhows that water more readily parts with ſome part of the heat it contains than mercury does, but has not the leaſt tendency to diſcover the quantity contained in either.

Dr Crawford, as we have already ſeen, calls the *degree*, or, if we may vary the phraſe, the *quantity of power* or *element (fluid*, if we may ſubſtitute a ſynonymous word) exiſting or preſent in any body, its *abſolute heat*; and lays down a rule for determining the

77 Dr Crawford's method of determining the proportional quantities of heat.

proportional quantities of heat in different bodies. "It will appear (ſays he) from the experiments afterwards recited, that if a pound of water and a pound of diaphoretic antimony have a common temperature, the quantity of abſolute heat contained in the former is nearly four times that contained in the latter." —The manner in which he illuſtrates this is as follows.

"If four pounds of diaphoretic antimony at 20 be mixed with one pound of ice at 32, the temperature will be nearly 26: the ice will be cooled ſix degrees, and the antimony heated ſix. If we reverſe the experiment, the effect will be the ſame. That is, if we take ſix degrees of heat from four pounds of antimony, and add it to a pound of ice, the latter will be heated ſix degrees. The ſame quantity of heat, therefore, which raiſes a pound of ice ſix degrees, will raiſe four pounds of antimony ſix degrees.

"If this experiment be made at different temperatures, we ſhall have a ſimilar reſult. If, for example, the antimony at 15, or at any given degree below the freezing point, be mixed with the ice at 32, the heat of the mixture will be the arithmetical mean between that of the warmer and colder ſubſtance. And ſince the capacities of bodies are permanent as long as they retain the ſame form, we infer, that the reſult would be the ſame if the antimony were deprived of all its heat, and were mixed with the ice at 32. But it is evident, that in this caſe the ice would communicate to the antimony the half of its abſolute heat. For if 200 below froſt be conceived to be the point of total privation, the antimony will be wholly deprived of its heat when cooled to 200 degrees below 32, and the heat contained in the ice when at 32 will be 200 degrees. If we now ſuppoſe them to be mixed together, the temperature of the mixture will be half the exceſs of the hotter above the colder, or the ice will

be

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be cooled 100 degrees and the antimony heated 100. The one half of the heat, therefore, which was contained in the ice previous to the mixture will be communicated to the antimony; from which it is manifest, that after the mixture the ice and antimony must contain equal quantities of absolute heat.

"To place this in another light, it has been proved, that the same quantity of heat which raises a pound of ice six degrees will raise four pound of antimony six degrees. And as the capacities of bodies, while they retain the same form, are not altered by a change of temperature; it follows, that the same quantity of heat which raises the ice 200 degrees, or any given number of degrees, will raise the antimony an equal number of degrees.

"A pound of ice, therefore, and four pounds of antimony, when at the same temperature, contain equal quantities of absolute heat. But it appears from the third general fact (nº 67.), that four pounds of antimony contain four times as much absolute heat as one pound of antimony; and hence the quantity of absolute heat in a pound of ice is to that in a pound of antimony as four to one."

78 His method insufficient.

From this quotation it is evident, that, notwithstanding all the distinctions which Dr Crawford has laid down betwixt absolute heat and temperature, it is only the *quantity* of the latter that can be measured; and all that we can say concerning the matter is, that when certain bodies are mixed together, some of them part with a greater quantity of heat than others; but how much they *contain* must remain for ever unknown, unless we can fall on some method of measuring the quantity of heat as we do that of any other fluid.

79 Nicholson's account of the theories of heat.

Mr Nicholson, who has collected the principal opinions on the subject of heat, seems undetermined whether to believe the doctrine of Boyle or of Boerhave on the subject. "There are two opinions (says he) concerning heat. According to one opinion, heat consists in a vibratory motion of the parts of bodies among each other, whose greater or less intensity occasions the increase or diminution of temperature. According to the other opinion, heat is a subtile fluid that easily pervades the pores of all bodies, causing them to expand by means of its elasticity or otherwise. Each of these opinions is attended with its peculiar difficulties. The phenomena of heat may be accounted for by either of them, provided certain suppositions be allowed to each respectively; but the want of proof of the truth of such suppositions renders it very difficult, if not impossible, to decide as yet whether heat consists merely in motion or in some peculiar matter. The word *quantity*, applied to heat, will therefore denote either motion or matter, according to the opinion made use of, and may be used indefinitely without determining which.

80 Advantages of the doctrine that heat is caused by vibration,

"The chief advantage which the opinion that heat is caused by mere vibration possesses, is its great simplicity. It is highly probable, that all heated bodies have an intestine motion, or vibration of their parts; and it is certain that percussion, friction, and other methods of agitating the minute parts of bodies, will likewise increase their temperature. Why, then, it is demanded, should we multiply causes, by supposing the existence of an unknown fluid, when the mere vibration of parts which is known to obtain may be applied to explain the phenomena?"

81 Answer to Mr Nicholson's argument.

To this the reply is obvious, that the vibration of parts is an *effect*; for matter will not begin to move of itself: and if it is an effect, we must suppose a cause for it; which, though we should not call it a fluid, would be equally unknown and inexplicable with that whose existence is asserted by those who maintain that fire is a fluid *per se*. Dr Cleghorn, however, in the dissertation already quoted, asserts, that "heat is occasioned by a certain fluid, and not by motion alone, as some eminent writers have imagined: because, 1. Those who have adopted the hypothesis of motion could never even prove the existence of that motion for which they contended; and though it should be granted, the phenomena could not be explained by it. 2. If heat depended on motion, it would instantaneously pass through an elastic body; but we see that heat passes through bodies slowly like a fluid. 3. If heat depended on vibration, it ought to be communicated from a given vibration in proportion to the quantity of matter; which is found not to hold true in fact. On the other hand, there are numberless arguments in favour of the opinion that heat proceeds from elementary fire. 1. Mr Locke hath observed, that when we perceive a number of qualities always existing together, we may gather from thence that there really is some substance which produces these qualities. 2. The hypothesis of elementary fire is simple and agreeable to the phenomena. 3. From some experiments made by Sir Isaac Newton, it appears, that bodies acquire heat and cold *in vacuo*, until they become of the same temperature with the atmosphere; so that heat exists in the absence of all other matter, and is therefore a substance by itself."

82 Dr Cleghorn's proof that heat is occasioned by a fluid.

83 Difficulties concerning the nature and properties of Fire.

But though these and other arguments seem clearly to establish the point that fire or heat is a distinct fluid, we are still involved in very great difficulties concerning its nature and properties. If it be supposed a fluid, it is impossible to assign any limits to its extent; and we must of necessity likewise suppose that it pervades the whole creation, and consequently constitutes an absolute plenum, contrary to a fundamental principle of the received system of natural philosophy. But if this is the case, it is vain to talk of its being absorbed, accumulated, collected, or attracted by different bodies, since it is already present in all points of space; and we can conceive of terrestrial bodies no otherwise than as sponges thrown into the ocean, each of which will be as full of fluid as it can hold. The different capacities will then be similar to the differences between bits of wood, sponge, porous stones, &c. for containing water; all of which depend entirely on the structure of the bodies themselves, and which, unless we could separate the water by pressure, or by evaporation, would be for ever unknown. Supposing it were impossible to collect this water in the manner we speak of, we could only judge of the quantity they contained by the degree to which they swelled by being immersed in it. It is easy to see, however, that such a method of judging would be very inadequate to the purpose, as substances might contain internal cavities or pores in which water could lodge without augmenting the external bulk. This would suggest another method of judging of the quantity, namely, the specific gravity;

vity; and we might reaſonably ſuppoſe, that ſubſtances of the greateſt ſpecific gravity would contain the ſmalleſt quantity of water, though ſtill we could by no means determine what quantity they did contain, unleſs we could lay hold of the element itſelf.

This ſeems to be very much the caſe with elementary fire, if we ſuppoſe it to be a fluid *per ſe*. We judge of its preſence by the degree of expanſion which one heated body communicates to another: but this is only ſimilar to the calculation of the quantity of moiſture a ſponge or any other body contains, by what it communicates to wood when it comes into contact with it; which never could be ſuppoſed to carry the leaſt pretenſions to accuracy, though we ſhould aſcertain it with all imaginable exactneſs. It is likewiſe probable, that the moſt denſe bodies contain the ſmalleſt quantity of fire, as they generally communicate leſs when heated to an equal temperature than thoſe which are more rare, though we are far from having any perfect knowledge in this reſpect.

84 Difficulty ariſing from the ſuppoſition that heat diffuſes itſelf equally.

But the greateſt difficulty of all will be, on the ſuppoſition that heat is a fluid, and an omnipreſent one (which it muſt be, or there would be ſome places where bodies could not be heated), to anſwer the queſtion, Why are not all bodies of an equal temperature, excepting only the differences ariſing from their ſpecific denſities, which render ſome capable of containing a greater quantity than others?—The difficulty will not be leſſened, though the omnipreſence of the fluid ſhould be given up, if we ſuppoſe, as is generally done, that heat has a tendency to diffuſe itſelf equably every way. If it has this tendency, what hinders it from doing ſo? Why doth not the heat from the burning regions of the torrid zone diffuſe itſelf equally all over the globe, and reduce the earth to one common temperature? This indeed might require time; but the experience of all ages has ſhown that there is not the leaſt advance towards an equality of temperature. The middle regions of the earth continue as hot, and the polar ones as cold, as we have any reaſon to believe they were at the creation of the world, or as we have any reaſon to believe they will be while the world remains. This indeed is one of the many inſtances of the impropriety of eſtabliſhing general laws from the trifling experiments we are capable of making, and which hold good only on the narrow ſcales on which we can make them, but are utterly inſufficient to ſolve the phenomena of the great ſyſtem of nature, and which can be ſolved only by obſerving other phenomena of the ſame ſyſtem undiſturbed by any manoeuvres of our own.

85 Another from the ſeeming diſappearance of the heat.

Again, ſuppoſing the objection already made could be got over, and ſatisfactory reaſons ſhould be given why an equilibrium of temperature in the earth and its atmoſphere ſhould never be obtained, it will by no means be eaſy to tell what becomes of the heat which is communicated to the earth at certain times of the year. This difficulty, or ſomething ſimilar, Dr Crawford ſeems to have had in view when treating of the effects of the evolution and abſorption of heat. Thus, ſays he, "the Deity has guarded againſt ſudden viciſſitudes of heat and cold upon the ſurface of the earth.

86 Dr Crawford's ſolution.

"For if heat were not evolved by the proceſs of congelation, all the waters which were expoſed to the influence of the external air, when its temperature was reduced below 32°, would ſpeedily become ſolid; and, at the moment of congelation, the progreſs of cooling would be as rapid at it was before the air had arrived at its freezing point.

"This is manifeſt from what was formerly obſerved reſpecting the congelation of different fluids. It was ſhown, that if the velocities of the ſeparation of heat were equal, the times of the congelation would be in proportion to the quantities of heat which the fluids gave off from an internal ſource in the freezing proceſs. Whence it follows, that if no heat were evolved, the congelation ſhould be inſtantaneous.

"In the preſent ſtate of things, as ſoon as the atmoſphere is cooled below 32°, the waters begin to freeze, and at the ſame time to evolve heat; in conſequence of which, whatever may be the degree of cold in the external air, the freezing maſs remains at 32°, until the whole is congealed; and as the quantity of heat extricated in the freezing of water is conſiderable, the progreſs of congelation in large maſſes is very ſlow.—That the abſorption and extrication of heat in the melting and freezing of bodies has a tendency to retard the progreſs of theſe proceſſes, is remarked by Mr Wilkie in his eſſay on latent Heat.—The ſame doctrine is likewiſe taught by Dr Black in his lectures.

87 Severity of the cold in the northern regions mitigated by the production of ice.

"In the northern and ſouthern regions, therefore, upon the approach of winter, a quantity of elementary fire is extricated from the waters, proportional to the degree of cold that prevails in the atmoſphere. Thus the ſeverity of the froſt is mitigated, and its progreſs retarded; and it would ſeem that, during this retardation of the cooling proceſs, the various tribes of animals and vegetables which inhabit the circumpolar regions gradually acquire power of reſiſting its influence.

88 Inundations prevented by the ſlowneſs with which congealed water melts.

"On the contrary, if, in the melting of ice, a quantity of heat were not abſorbed, and rendered inſenſible, that ſubſtance, when it was expoſed to a medium warmer than 32°, would ſpeedily become fluid, and the proceſs of heating would be as rapid as if no alteration in its form had taken place. If things were thus conſtituted, the vaſt maſſes of ice and ſnow which are collected in the frigid zones would, upon the approach of ſummer, ſuddenly diſſolve, and great inundations would annually overflow the regions near to the poles.

"But by the operation of the law of the abſorption of heat, when the ice and ſnow upon the return of ſpring have arrived at 32°, they begin to melt, and at the ſame time to imbibe heat: during this proceſs, a large quantity of elementary fire becomes inſenſible; in conſequence of which the earth is ſlowly heated, and thoſe gradual changes are produced which are eſſential to the preſervation of the animal and vegetable kingdoms.

89 Equal diſtribution of heat promoted by its abſorption and evolution.

"We may remark, in the laſt place, that this law not only reſiſts ſudden changes of temperature, but that it likewiſe contributes to a more equal diſtribution of the principle of heat throughout the various parts of the earth, in different ſeaſons and climates. Thus the diurnal heats are moderated by the evaporation of the waters on the earth's ſurface, a portion of the fire derived from the ſun being abſorbed and extinguiſhed by the vapours at the moment of their aſcent. On the approach of night the vapours are again condenſed, and falling in the form of dew, communicate

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to the air and to the earth the fire which they had imbibed during the day.

"It was before shown, that, in the regions near to the poles, when the vernal and summer heats prevail, provision is made for tempering the severity of the winter cold, a quantity of elementary fire, upon the dissolution of the ice and snow, being absorbed by the waters, and deposited, as it were, in a great magazine for the purpose of mitigating the intensity of the cold when the frost returns.

90 Heat of the torrid zone thus mitigated.

"From the experiments of Hales, Halley, and Watson, it appears, that vast quantities of water are continually converted into vapour by the action of the solar rays upon the portion of the earth's surface which is exposed to the light; and by the celebrated discovery of Dr Black, it is proved, that, in the process of evaporation, much elementary fire is absorbed. It is manifest, that this cause will have a powerful influence in mitigating the intensity of the heat in the torrid zone, and in promoting a more equal diffusion of it through the earth. For a considerable portion of the heat, which is excited by the action of the solar rays upon the earth's surface within the tropics, is absorbed by the aqueous vapours, which being collected in the form of clouds, are spread like a canopy over the horizon, to defend the subjacent regions from the direct rays of the sun. A great quantity of elementary fire is thus rendered insensible in the torrid zone, and is carried by the dispersion of the vapours to the north and to the south, where it is gradually communicated to the earth when the vapours are condensed."

91 This solution totally insufficient to remove the difficulty.

That all this takes place, as the Doctor has advanced, cannot be denied; but, by allowing it, the difficulty is not removed in the smallest degree, as will appear from a due consideration of the phenomena which he himself has mentioned. He owns that the sun communicates fire to the earth: the question is, What becomes of it, seeing the emission is continual? In summer, the air, the earth, and the water, are heated to a certain degree. On the sun's declining southward, the air first loses its heat. Whither does it go? It does not ascend into the higher regions of the atmosphere, for these are constantly found colder than the parts below. It does not descend to the earth and water; for these give out the quantity they had absorbed, as Dr Crawford observes. Neither does it go laterally to the southern regions; for they are constantly very hot, and ought to impart their heat to those farther north, instead of receiving any from them. How comes it then, that the atmosphere seems perpetually to receive heat without ever being satiated? or if the heat cannot be found going off either upwards, downwards, or sideways, how are we to account for its disappearance?

92 Heat most probably the action of an omnipresent fluid.

This question seems to be altogether unanswerable on the supposition that heat is occasioned by the mere presence of a fluid; but if we suppose it to be only a particular mode of action of an omnipresent fluid, the whole difficulty vanishes at once.—On this supposition indeed the question will naturally arise, Whence does this motion proceed, or by what is its action in general determined? Dr Berkenhout, in enumerating the properties of matter, exempts fire from two of those usually ascribed to other material substances, viz gravitation and the *vis intertiæ*. "According to the philosophers (says he), matter cannot move without being either impelled or attracted. I doubt much whether this be true of fire, and whether, when uncombined, motion be not one of its essential properties.—Gravitation seems also to be no property of fire, which moves with equal facility in all directions, and may be accumulated in hard bodies to any degree without increasing their weight. Fire, being the cause of volatility, seems rather to be in constant counteraction to gravity."

93 Fire seems destitute of gravity and *vis inertiæ*.

But however essential we may suppose the motion of fire to be to it, there cannot be any self-existent mobility in its parts, otherwise it would soon be diffused equally throughout the universe, and the temperature of the whole reduced to an equilibrium. According to the present constitution of nature, we see that the distribution of heat is principally owing to the sun; and what we call its *quantity*, depends on the position of the sun with regard to terrestrial objects and the length of time they are exposed to his rays. Heat is not produced while the rays have a direct passage; and therefore fluids through which they pass easily, as air, are not heated by the rays of the sun. But when the rays are impeded in their course, and reflected in considerable quantity, a degree of heat takes place, which is always greater or less in proportion to the intensity of the rays.—In the reflecting substance, the heat will be comparatively greater in proportion to the quantity of rays which are absorbed or stopped in their course by it: but in any substance interposed betwixt the sun and the reflecting body, the heat is proportional to the quantity of rays reflected.—Now it is plain, that when the particles of light fall upon any opaque substance, and enter its pores, which by their extreme subtilty they are well calculated to do, they must make an attempt to pass directly through it in their natural course; but as this cannot be done, they will push laterally, and in all directions, in consequence of being perpetually urged by the impulse of the light coming from the sun: and thus an action will be propagated in all directions as radii from a centre towards a circumference, which when it takes place in that subtile fluid always produces what we call *heat*.

94 Distribution of heat owing to the sun.

95 How heat is produced by the sun's rays.

In completing the system of nature, we perceive three kinds of fluids of extreme subtilty, and very much resembling one another, viz. fire, light, and electricity. That it should be agreeable to vulgar conceptions to suppose these all to be ultimately the same, is not surprising; and on examining the evidence of their identity, it will certainly be found exceedingly strong. They all agree in the property of exciting the sensation of heat in certain circumstances, and in not doing so in others. Fire, we know, in the common acceptation of the word, always does so; but when it assumes the latent and invisible state, as in the formation of vapour, it lays aside this seemingly essential property, and the vapour is cold to the touch.—Light, when collected in a focus by a burning glass, i. e. when its rays converge towards a centre, and diverge or attempt to diverge from one, produces heat also: and so does the electric fluid; for it has been found that the aura converging from a very large conductor to the point of a needle, is capable of setting on fire a small cartridge of gunpowder, or a quantity of tinder surrounding it *. There seems also to be a connection betwixt

96 Proofs of the identity of fire, light, and electricity.

fire

* See *Electricity*.

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fire and electricity in another way; for in proportion as heat is diminiſhed, or the bodies are cooled, electricity ſucceeds in its place. Thus all electric bodies by heat become conductors of electricity, and cannot be excited or made to ſhow any ſigns of containing that fluid; but as ſoon as the heat is removed, their electric property returns. Water is naturally a conducting ſubſtance: by being frozen its conducting power is leſſened, which ſhows an approach to electricity; and, by being cooled down to 20° below 0 of Fahrenheit, the ice actually becomes electric, and will emit ſparks by friction like glaſs*. The atmoſphere is a natural electric: but by a certain degree of heat it loſes this property, and becomes a conductor; nor is there any doubt that its electric properties are increaſed in proportion to the degree of cold imparted to it. In the winter time, therefore, we muſt conſider the frozen ſurface of the earth, the water, and the atmoſphere of the polar regions, as forming one electrical machine of enormous magnitude; for the natural cold of theſe countries is often ſufficient to cool the water to more than 20° below 0, and conſequently to render it an electric. That this is really the caſe, appears from the exceſſively bright aurora borealis and other electric appearances, far exceeding any thing obſerved in this country. In the ſummer time, however, no ſuch appearances are to be ſeen, nor any thing remarkable except an exceſſive heat from the long continuance of the ſun above the horizon. This quantity of heat then being ſucceeded by a proportionable quantity of electricity in winter, it is impoſſible to avoid concluding that the heat in ſummer becomes electric fluid in winter, which, going off through the celeſtial expanſe, returns again to the grand ſource of light and heat from which it originally came; thus making room for the ſucceeding quantities which are to enliven the earth during the following ſummer.

97 Connection between fire or heat and electricity.

* See *Electricity*.

98 Exceſſive electricity of the polar regions in winter.

99 Heat in ſummer becomes electric fluid in winter.

Thus the diſappearance of heat in winter, and of electricity in ſummer, in theſe countries, will be very naturally and eaſily accounted for. It is true, that the phenomena of thunder and lightning ſhow the exiſtence of this fluid in vaſt quantities during the ſummer ſeaſon: but theſe phenomena are only partial, and though formidable to us, are trifling in compariſon with the vaſt quantities of electric matter diſcharged by the continual flaſhing of the aurora borealis, not to mention the fire-balls and meteors called *falling ſtars*, which are very often to be ſeen in the northern countries. In the ſummer-time, the air which is an electric, heated by the rays of the ſun, is excited or made to part with the fluid to the vapours contained in it; and it is the unequal or oppoſite electricity of the clouds to one another, or to the earth, which produces the lightning. But in winter, when the air, earth, and vapours, all become electric, they cannot diſcharge ſparks from one to another as before; but the whole, as one connected and vaſt electrified apparatus, diſcharges the matter almoſt in a continued ſtream for many months.

100 Why thunder and lightning take place in ſummer and not in winter.

From a conſideration of theſe and other phenomena of nature, as well as of the beſt experiments which have hitherto been made, we muſt conſider fire in the abſtract as an omnipreſent fluid, of ſuch ſubtilty as to prevade all terreſtrial ſubſtances. When by any means it is made to diverge every way as from a centre, there it operates as heat; expands, rarefies, or burns, according to the intenſity of its action. Proceeding in ſtraight and parallel lines, or ſuch as diverge but little, it acts as light, and ſhows none of that power diſcoverable in the former caſe, though this is eaſily diſcoverable by making it converge into a focus. In a quieſcent ſtate, or where the motion is but little, it preſſes on the ſurfaces of bodies, contracts and diminiſhes them every way in bulk, forces out the expanding fluid within their pores, and then acts as cold. In this caſe alſo, being obliged to ſuſtain the vehement action of that part of the fluid which is in motion, it flies with violence to every place where the preſſure is leſſened, and produces all the phenomena of Electricity.

101 Heat, light, cold, and electricity, the effects of one univerſal fluid

Nature of Heat.

§ 1. *Of the Nature of Heat.*

102 Particular ſolution of the phenomena of heat.

The manner in which the phenomena of heat may be ſolved, and its nature underſtood, will appear from the following propoſitions.

1. It is in all caſes obſerved, that when light proceeds in conſiderable quantity from a point, diverging as the radii of a circle from its centre, there a conſiderable degree of heat is found to exiſt, if an opaque body, having no great reflective power, is brought near that point.

2. This action of the light, therefore, may be accounted the ultimate cauſe of heat, without having recourſe to any farther ſuppoſitions; becauſe nothing elſe beſides this action is evident to our ſenſes.

3. If the point from which the rays are emitted is placed in a tranſparent medium, ſuch as air or water, that medium, without the preſence of an opaque body, will not be heated.

4. Another cauſe of heat, therefore, is the reſiſtance of the parts of that body on which the light falls, to the action mentioned in Prop. 1. Where this reſiſtance is weak, as in the caſes juſt mentioned, the heat is either nothing, or very little.

5. If a body capable of reflecting light very copiouſly is brought near the lucid point, it will not be heated*.

* See the article *Burning-Glaſs*.

6. A penetration of the light, therefore, into the ſubſtance of the body, and likewiſe a conſiderable degree of reſiſtance on the part of that body to the action of the light, are the requiſites to produce heat.

7. Thoſe bodies ought to conceive the greateſt degrees of heat into whoſe ſubſtance the light can beſt penetrate, *i. e.* which have the leaſt reflective power, and which moſt ſtrongly reſiſt its action; which is evidently the caſe with black and ſolid ſubſtances.

8. By heat all bodies are expanded in their dimenſions every way, and that in proportion to their bulk and the quantity of heat communicated to them.

9. This expanſion takes place not only by an addition of *ſenſible* heat, but likewiſe of that which is *latent*. Of this laſt we have a remarkable inſtance in the caſe of ſnow mixed with ſpirit of nitre. The ſpirit of nitre contains a certain quantity of latent heat, which cannot be ſeparated from it without effecting a change on the ſpirit itſelf; ſo that, if deprived of this heat, it would no longer be ſpirit of nitre.—Beſides this, it contains a quantity of ſenſible heat, of a great part of which it may be deprived, and yet retain its characteriſtic properties as nitrous acid. When it is poured upon ſnow, the latter is immediately melted by the action of the latent heat in the acid. The ſnow cannot

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be melted or converted into water, without imbibing a quantity of latent heat, which it receives immediately from the acid which melts it. But the acid cannot part with the heat without decomposition; to prevent which, its sensible heat occupies the place of that which has entered the snow and liquefied it. The mixture then becomes exceedingly cold, and the heat forces into it from all the bodies in the neighbourhood; so that, by the time it has recovered that quantity of sensible heat which was lost, or arrived at the temperature of the atmosphere around it, it will contain a considerably larger quantity of heat than it originally did, and is therefore observed to be expanded in bulk. Another instance of this expansive power of latent heat is in the case of steam, which always occupies a much larger space than the substance from which it was produced; and this whether its temperature is greater or less than the surrounding atmosphere.

10. The difference between latent and sensible heat, then, as far as we can conceive, is, that the expansive power of the former is directed only against the particles of which the body is composed; but that of the latter is directed also against other bodies. Neither doth there seem to be any difference at all between them farther than in quantity. If water, for instance, hath but a small quantity of heat, its parts are brought near each other, it contracts in bulk, and feels cold. Still, however, some part of the heat is detained among the aqueous particles, which prevents the fluid from congealing into a solid mass. But, by a continuation of the contracting power of the cold, the particles of water are at last brought so near each other that the internal or *latent* heat is forced out. By this discharge a quantity of air is also produced, the water is congealed, and the ice occupies a greater space than the water did; but then it is full of air-bubbles, which are evidently the cause of its expansion. The heat then becomes *sensible*, or, as it were, lies on the outside of the matter; and consequently is easily dissipated into the air, or communicated to other bodies. Another way in which the latent heat may be extricated is by a constant addition of sensible heat. In this case the body is first raised into vapour, which for some time carries off the redundant quantity of heat. But as the quantity of this heat is continually increased, the texture of the vapour itself is at last totally destroyed. It becomes too much expanded to contain the heat, which is therefore violently thrown out on all sides into the atmosphere, and the body is said to burn, or be on fire. See COMBUSTION, FLAME, and IGNITION.

11. Hence it follows, that those bodies which have the least share of latent heat, appear to have the greatest quantity of sensible heat; but this is only in appearance, for the great quantity they seem to contain is owing really to their inability to contain it. Thus, if we can suppose a substance capable of transmitting heat through it as fast as it received it; if such a substance was set over a fire, it would be as hot as the fire itself, and yet the moment it was taken off, it would be perfectly cool, on account of its incapacity to detain the heat among the particles of which it was composed.

12. The heat, therefore, in all bodies consists in a certain violent action of the elementary fire within them tending from a centre to a circumference, and thus making an effort to separate the particles of the body from each other, and thereby to change its form or mode of existence. When this change is effected, bodies are said to be dissipated in vapour, calcined, vitrified, or burnt, according to their different natures.

13. Inflammable bodies are such as are easily raised in vapours; that is, the fire easily penetrates their parts, and combines with them in such quantity, that, becoming exceedingly light, they are carried up by the atmosphere. Every succeeding addition of heat to the body increases also the quantity of latent heat in the vapour, till at last, being unable to resist its action, the heat breaks out all at once, the vapour is converted into flame, and is totally decomposed. See the article FLAME, and Prop. 10.

14. Uninflammable bodies are those which have their parts more firmly connected, or otherwise disposed in such a manner, that the particles of heat cannot easily combine with them or raise them into vapour.

15. Heat therefore being only a certain mode of the action of elementary fire, it follows, that the capacity of a body for containing it, is only a certain constitution of the body itself, or a disposition of its parts, which can allow the elementary fire contained in it to exert its expansive power upon them without being dissipated on other bodies. Those substances which allow the expansive power of the fire to operate on their own particles are said to contain a great deal of heat; but those which throw it away from themselves upon other bodies, though they feel very hot, yet philosophically speaking they contain very little heat.

16. What is called the *quantity* of heat contained in any substance, if we would speak with the strictest propriety, is only the apparent force of its action, either upon the parts of the body itself, or upon other bodies in its neighbourhood. The expansive force of the elementary fire contained in any body upon the parts of that body, is the *quantity of latent heat* contained in it; and the expansive force of the fire exerted upon other bodies which touch or come near it, is the *quantity of sensible heat* it contains.

17. If what we call *heat* consists only in a certain action of that fluid called *elementary fire*, namely, its expansion, or acting from a centre to a circumference, it follows, that if the same fluid act in a manner directly opposite to the former, or press upon the particles of a body as from a circumference to a centre, it will then produce effects directly opposite to those of heat, i. e. it will then be absolute *cold*, and produce all the effects already attributed to COLD. See that article.

18. If heat and cold then are only two different modifications of the same fluid, it follows, that if a hot body and a cold one are suddenly brought near each other, the heat of the one ought to drive before it a part of the cold contained in the other, *i. e.* the two portions of elementary fire acting in two opposite ways, ought in some measure to operate upon one another as any two different bodies would when driven against each other. When a hot and a cold body therefore are brought near each other, that part of the cold body farthest from the hot one ought to become colder than before, and that part of the hot body farthest from the cold one ought to become hotter than before.

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19. For the same reason, the greatest degree of cold in any body ought to be no obstacle, or at least very little, to its conceiving heat, when put in a proper situation. Cold air, cold fuel, &c. ought to become as intensely heated, and nearly as soon, as that which is hotter.

The two last propositions are of great importance. When the first of them is thoroughly established, it will confirm beyond a doubt, that cold is a *positive*, as well as heat; and that each of them has a separate and distinct power, of which the action of its antagonist is the only proper limit; *i. e.* that heat can only limit the power of cold, and *vice versa*. A strong confirmation of this proposition is the experiment related by M. Geoffroy; an account of which is given under the article COLD. Another, but not so well authenticated, is related under the article CONGELATION.—De Luc's observation also, mentioned by Dr Cleghorn, affords a pretty strong proof of it; for if the lower parts of the atmosphere are cooled by the passage of the sun's rays at some distance above, and it hath been already shown that they do not *attract* the heat from the lower parts, it follows, that they must *expel* part of the cold from the upper regions.—The other proposition, when fully established, will prove, that heat and cold are really convertible into one another; which indeed seems not improbable, as we see that fires will burn with the greatest fierceness during the time of intense frosts, when the coldest air is admitted to them; and even in those dismal regions of Siberia, when the intense cold of the atmosphere is sufficient to congeal quicksilver, it cannot be doubted that fires will burn as well as in this country; which could not happen if heat was a fluid *per se*, and capable of being carried off, or absolutely diminished in quantity, either in any part of the atmosphere itself, or in such terrestrial bodies as are used for fuel.

§ 2. *Of the general Effects of Heat.*

HAVING said thus much concerning the nature of heat in general, we come now to a particular explanation of its several effects, which indeed constitute the whole of the active part of chemistry.—These are,

I. *Expansion*, or increase of bulk in every direction. This is a necessary consequence of the endeavour which the fluid makes to escape in all directions, when made to converge into a focus. The degree of expansion is unequal in different bodies, but in the same body is always proportionable to the degree of heat applied. There are two different instruments in use for ascertaining the degrees of expansion; and as we have already shown, that the degree of heat can only be known by the expansion, these effects of heat upon the instrument are usually taken for the degrees of heat themselves. These instruments are called the THERMOMETER and PYROMETER. The former is composed of a glass tube, with a globe or rather oval tube at one end, and exactly closed at the other: it is most usually filled with mercury or spirit of wine; but mercury is generally preferred on account of its expansions being more equable than those of any other fluid. It has the disadvantage, however, of being subject to congelation; which is not the case with spirit of wine, when very highly rectified. Spirit-of-wine thermometers, therefore ought not to be entirely disused, but seem rather a necessary part of the chemical apparatus, as well as those made of mercury.

103 Instruments for measuring the expansions of bodies.

104 Wedgewood's improvement of the thermometer.

As no thermometer made with any fluid can measure either the degrees of heat about the point at which it boils, or the degree of cold below which it congeals, instruments have been contrived by which the expansion of solid bodies, though much less than what is occasioned by an equal degree of heat in a fluid, may become visible. These were usually called *Pyrometers*; but Mr Wedgewood has lately contrived a method of connecting the two together, in which the highest degree of heat, exceeding even that of a glass-house furnace, may be measured as accurately as the more moderate degrees by the common mercurial thermometer. See THERMOMETER.

105 Instances of bodies expanding by cold.

Expansion in some cases does not appear to be the effect of heat, of which we have two remarkable instances, viz. of iron, which always expands in cooling after it has been melted; and of water, which expands with prodigious force in the act of freezing. The power with which iron expands in the act of passing from a fluid to a solid state, has never been measured, nor indeed does it seem easy to do so; but that of freezing water has been accurately computed.

106 Prodigious force exerted by water in freezing.

This was done by the Florentine Academicians, who having filled an hollow brass ball of an inch diameter, with water, exposed it to a mixture of snow and salt, in order to congeal the water, and try whether its force was sufficient to burst the ball or not. The ball, being made very strong, resisted the expanding force of the water twice, even though a considerable part of its thickness had been pared off when it was perceived too strong at first. At the third time it burst; and by a calculation founded on the thickness of the globe and the tenacity of the metal, it was found that the expansive power of a spherule of water only one inch in diameter, was sufficient to overcome a resistance of more than 27,000 pounds, or 13 tons and an half.

107 Used as an argument for the existence of cold as a positive substance.

A power of expansion so prodigious, little less than double that of the most powerful steam-engines, and exerted in so small a body, seemingly by the force of cold, was thought to be a very powerful argument in favour of those who suppose cold to be a positive substance as well as heat; and indeed contributed not a little to embarrass the opposite party.

108 Explained by Dr Black's theory of latent heat.

Dr Black's discovery of latent heat, however, has now afforded a very easy and natural explication of this phenomenon. He has shown, that, in the act of congelation, water is not cooled more than it was before, but rather grows warmer: that as much heat is discharged, and passes from a latent to a sensible state, as, had it been applied to water in its fluid state, would have heated it to 135°.

109 The expansion produced by the extrication of air-bubbles.

In this process the expansion is occasioned by a great number of minute bubbles suddenly produced. These were formerly supposed to be formed of *cold* in the abstract; and to be so subtile, that, insinuating themselves into the substances of the fluid, they augmented its bulk, at the same time that, by impeding the motion of its particles upon each other, they changed it from a fluid to a solid. Dr Black, however, has demonstrated, that these are only air extricated during the congelation; and to the extrication of this air he very justly attributes the prodigious expansive force exerted by freezing water. The

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only question, therefore, which now remains is, By what means this air comes to be extricated, and to take up more room than it naturally does in the fluid? To this we can scarce give any other answer, than that part of the heat which is discharged from the freezing water combines with the air in its unelastic state, and, by restoring its elasticity, gives it that extraordinary force, as we see also in the case of air suddenly extricated in the explosion of gunpowder. Thus expansion, even in the case of freezing, is properly an effect of heat; and must therefore be con[illegible] as a phenomenon uniformly and certainly attending the action of heat, and in all cases to be ascribed to it.

110 This air extricated by part of the heat contained in the water.

111 Capacity of a body for containing heat, the same with the action of heat upon that body.

The only way in which the element or fluid of fire can be supposed to act, and the way in which we can have a rational idea of its being able to produce both heat and cold according to the diversity of its action, has been already explained so fully, that it is needless at present to enter into any further discussion of the subject. It will easily appear, that the *capacity* for containing heat is nothing different from the action of heat upon that body in expanding, and at last altering its form in such a manner, as either to be able to insinuate itself among the particles in much greater quantity than before, still retaining its internal action, though the external one becomes imperceptible; or scattering them in such a manner, that it breaks forth in great quantity in its peculiar appearances of fire and light; in the former case producing vapour or smoke, and in the latter flame, as shall afterwards be more fully explained. It must likewise appear, that to determine the quantity of heat in any body is altogether impossible: and with regard to the lowest degree of heat, or total expulsion of that fluid, so far from being able to determine what it is, the probability must be, that nature does not admit of any such thing; for if heat consists in the expansive action of a certain fluid, and cold in its opposite or contractile action, there is very little reason to suppose that the constitution of nature will allow any one of these actions intirely to cease, as it does not appear by what means it could again be renewed. Cold, as we have already seen, always tends to produce electricity; and the connexion betwixt that and fire is so strong, that we cannot suppose the former to be carried to any great extreme without producing the latter. Whatever we may therefore suppose concerning the capacities of different bodies for containing heat, or concerning the point of total privation of heat, must be altogether void of foundation. A rule, however, has been given by Mr Kirwan for finding the point of total privation, which, together with its demonstration, we shall subjoin; and as it is necessary for the better understanding of this, to call to remembrance what has been said concerning the difference between the temperatures and specific heats of bodies, we shall insert an epitome of the doctrine from Mr Nicholson.

112 Impossibility of determining the quantity of heat any body contains.

113 Mr Nicholson's account of the capacities of bodies for containing heat, &c.

"If two equal bodies of different kinds and temperatures be brought into contact, the common temperature, will seldom, if ever, be the mean betwixt the two original temperatures; that is to say, the surplus of heat in the hotter body will be unequally divided between them, and the proportions of this surplus retained by each body will express their respective dispositions, affinities, or capacities for heat.—If, therefore, a given substance, as for example fluid water, be taken as the standard of comparison, and its capacity for heat be called one, or unity, the respective capacities of their bodies may be determined by experiment, and expressed in numbers in the same manner as specific gravities usually are. And because it is established as well from reason as experiment, that the same capacity for heat obtains in all temperatures of a given body, so long as its state of solidity, fluidity, or vapour is not changed, it will follow, that the whole quantities of [illegible] in equal bodies of a given temperature will be as those capacities. And as the respective quantities of matter, in bodies of equal volume, give the proportions of their specific gravities, so the respective quantities of heat in bodies of equal weight and temperature give the proportions of their specific heats.

"A greater capacity for heat, or greater specific heat, in a given body, answers the same purpose with respect to temperature as an increase of the mass; or the quantity of heat required to be added or subducted, in order to bring a body to a given temperature, will be as its capacity or specific heat.

"The capacities not only differ in various bodies, but also in the same body, according as it is either in a solid, fluid, or vaporous state. All the experiments hitherto made conspire to show, that the capacity, and consequently the specific heat, is greatest in the vaporous, less in the fluid, and least in the solid state.

"The quantity of heat that constitutes the difference between the several states, may be found in degrees of the thermometer. Thus if equal quantities of water at 162° and ice at 32° of temperature be mixed, the ice melts, and the common temperature becomes 32°; or otherwise, if equal quantities of frozen or fluid water, both at 32°, be placed in a like situation to acquire heat from a fire, the water will become heated to 162°, while the ice melts without acquiring any increase of temperature. In either case the ice acquires 130° of heat, which produces no other effect than rendering it fluid. Fluid water, therefore, contains not only as much more heat than ice, as is indicated by the thermometer, but also 130°, that is in some manner or other employed in giving it fluidity. And as fluid water cannot become ice without parting with 130° of heat besides what it had above 32° in its temperature; so also steam cannot become condensed into water without imparting much more heat to the matters it is cooled by, than water at the same temperature would have done.

"The heat employed in maintaining the fluid or vaporous form of a body, has been called latent heat, because it does not affect the thermometer.

114 Mr Kirwan's theorem for finding the point of total privation of heat.

"From the consideration of the specific heats of the same body in the two states of fluidity and solidity, and the difference between those specific heats, is deduced a method of finding the number of degrees which denote the temperature of any body immediately after congelation, reckoned from the natural zero, or absolute privation of heat. The rule is; multiply the degrees of heat required to reduce any solid to a fluid state, by the number expressing the specific heat of the fluid: divide this product by the difference between the numbers expressing the specific heat of the body in each state: the quotient will be the number of

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of degrees of temperature, reckoned from an abſolute privation of heat.

"This theorem is Mr Kirwan's, and may be proved thus. Let s repreſent the required temperature of the body juſt congealed, $l=$ the number of degrees that expreſs the heat required to reduce it to fluidity, $n=$ the ſpecific heat of the ſolid, and $m=$ the ſpecific heat of the fluid. Then $s+l : s :: m : n$. Whence $s=\frac{ln}{m-n}=$ the temperature from the natural zero in thermometrical degrees of the fluid. But becauſe the actual fall of the thermometer is to be produced by cooling the ſolid, we muſt pay attention to its capacity. The quantity of heat required to produce a given change of temperature in a body is as its capacity; and conſequently the changes of temperature, when the quantity of heat is given, will be inverſely as the capacities: therefore, $n : m :: \frac{ln}{m-n} : \frac{ln}{m-n} = s$. which is the rule abovementioned.

"If the data l, m, and n, be accurately obtained by experiment, in any one inſtance, and the difference between the zero of Fahrenheit's ſcale and the natural zero be thence found in degrees of that ſcale, this difference will ſerve to reduce all temperatures to the numeration which commences at the natural o. So that s being known in all caſes, if any two of the quantities l, m, or n, be given in any body, the other may be likewiſe had. For $l=\frac{sm-sn}{m}$; and $m=\frac{sn}{s-l}$ and $n=\frac{sm-lm}{s}$.

"To give an example of this curious rule, let it be required to determine how many degrees of refrigeration would abſolutely deprive ice of all its heat? The degrees of heat neceſſary to melt ice are 130; and the ſpecific heats of ice and water are as 9 to 10. The number 130 multiplied by 10, produces 1300, and divided by the difference between 9 and 10 quotes 1300: therefore if ice were cooled 1300 degrees below 32°, or to—1268 of Fahrenheit's ſcale, it would retain no more heat."

II. *Fluidity* is another effect of heat, and is capable of taking place in all bodies hitherto known, when the fire is carried to a certain pitch. Theories have been invented, by which fluidity was aſcribed to the ſmoothneſs and round figure of the particles whereof bodies were compoſed, and ſolidity to an angular or irregular figure. It has alſo been aſcribed to a ſtronger degree of attraction between the parts of ſolids

115 Fluidity to be aſcribed to the abſorption of heat.

than of fluids. Dr Black, however, has ſhown, that in the caſe of melting ice, we are certainly to aſcribe the acquired fluidity of the water to the abſorption of heat. This was determined by a deciſive experiment, in which he expoſed a Florence-flaſk full of water to the atmoſphere in a warm room, when he found that the heat in the air evidently left it, to flow into the ice in the bottle, and reduced it to fluidity. The air thus deprived of its heat, he felt ſenſibly deſcending like a cold blaſt from the bottle, and continuing to do ſo as long as any of the ice remained unthawed; yet after it was all melted, the temperature of the fluid was no more than 32°. Different degrees of heat are requiſite for converting different ſolids into fluids, for which ſee the *Table of Degrees of Heat*.

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This theory receives an additional confirmation from the quantity of heat which is always known to be produced by the converſion of a fluid into a ſolid. And that this is really the caſe appears, 1. From what happens in

116 Senſible heat produced by the converſion of a fluid into a ſolid.

the congelation of waters, it appears that ice is formed very ſlowly, and with ſeveral circumſtances which ſupport the theory.—Thus, if we ſuppoſe equal quantities of water to the air, which is perhaps 10 below froſt, and add to one of theſe a ſmall quantity of ſalt or ſpirit of wine, and obſerve the cooling of each, we ſhall find them both grow gradually colder, until they arrive at the temperature of froſt: after which the water containing the ſalt will continue to grow colder, until it has arrived at the temperature of the air, at the ſame time that only a ſmall quantity of the other water is converted into ice. Yet were the common opinion juſt, it ought all to have been congealed by this time; inſtead of which, it is ſcarce grown a degree colder during the whole time. Its remaining at the ſame temperature for ſo long a time, ſhows that it has been communicating heat to the atmoſphere; for it is impoſſible that any body can remain in contact with another that is colder, without communicating heat to it. Whence then comes this heat? There muſt be ſome ſource adding to the ſenſible heat of the water, ſo as to keep its temperature to the freezing point: and this ſource of heat muſt be very conſiderable; for it will continue to act for a very long time before the water is changed into ice; during all which time, even to the laſt drop, the water is not a degree colder than 32° of Fahrenheit's thermometer. This, therefore, is the *latent heat* of the water, which had formerly entered into it during its tranſition from ice to a fluid ſtate.

117 Argument in ſupport of the theory from water remaining fluid tho' cooled below 32°.

A ſtill ſtronger argument is derived from the following experiment; which evinces that the fluidity of water really depends upon its latent heat, and that the ſenſible heat is only a mean or condition to its containing the latent heat. This experiment conſiſts in expoſing water contained in a covered beer-glaſs to the air of a cold froſty night; and when the atmoſphere is at the temperature of perhaps 10° or 12° below froſt, the water will acquire that temperature without freezing: ſo that the fluidity of the water does not altogether depend on the quantity of ſenſible heat contained in it. The congelation, however, may be brought on by touching it with a bit of ice, with the extremity of a wire, by a ſhock upon the board, or otherwiſe diſturbing it; and we then find the temperature ſuddenly raiſed up to 32°. This ſhows plainly, that the water has a diſpoſition to retain the quantity of latent heat, upon which its fluidity muſt immediately and neceſſarily depend; and it retains it with a certain degree of force, ſo as to keep the water fluid in a temperature below that in which it uſually parts with the latent heat and congeals. By diſturbing it, however, we inſtantly bring on the congelation, which cannot take place without an extrication of the latent heat; which then, being changed into the ordinary or moveable heat, raiſes the thermometer as uſual. The quantity of heat diſcharged from the firſt ſmall portion of ice formed in the water is ſufficient to prevent any more latent heat from ſeparating, and conſequently from any more ice being produced till more of the ſenſible heat is abſtracted.

This doctrine extends not only to ſuch bodies as are actually converted from a ſolid to a fluid, or from

a fluid to a ſolid ſtate, but to ſuch as are in a kind of middle ſtate betwixt ſolidity and fluidity; for every degree of ſoftneſs depends on a certain degree of heat contained in the body.

118 How the cauſe of the ſoftneſs of bodies approaching to fluidity.

Thus, for inſtance, melted wax, allowed to cool ſlowly, ſoon becomes opaque and conſiſtent; but it muſt be colder ſtill before it attains its utmoſt degree of hardneſs. There is therefore a certain degree of heat below which every body is ſolid, and above which every one is fluid; the former being called the *congealing*, and the latter the *melting*, point of bodies.

119 Abſorption of heat the univerſal cauſe of fluidity.

By making experiments upon different ſubſtances, the Doctor was convinced that latent heat is the univerſal cauſe of fluidity; and the doctrine holds good in all the experiments that have hitherto been made upon ſpermaceti, bees-wax, and ſome of the metals. If they are melted, allowed to cool ſlowly, and a thermometer be immerſed into them, we find, that as long as they continue fluid, their ſenſible heat diminiſhes very faſt; but as ſoon as they begin to grow ſolid, the ſenſible heat continues greater than that of the air to which they are expoſed; and during all this time it is communicating heat to the air, without having its ſenſible heat diminiſhed; for the latent heat within the fluid gradually receives a ſenſible form, and keeps up the temperature, proving a ſource of ſenſible heat, which is communicated to the neighbouring bodies as well as the ſurrounding air. The ſoftneſs and ductility of bodies depend on this alſo.

120 Vapour formed by the abſorption of latent heat.

III. *Evaporation.* A third effect of the action of heat is that of converting bodies into vapour, by which they are rendered ſpecifically lighter than the ſurrounding atmoſphere, and enabled to riſe in it. To account for this, many theories have been invented; but that of Dr Black, who accounts for it, as well as fluidity from the abſorption of latent heat, is now univerſally received. The circumſtances by which he proves and illuſtrates his doctrine are the following:

1. When we attend to the phenomena of boiling water, in a tea kettle for inſtance, it may, when firſt put upon the fire, be about the temperature of 48° or 50°. In a quarter of an hour it will become heated to 212°. It then begins to boil, and has gained 162° of vapour in that time. Now, if the converſion of it into vapour depended on the quantity of ſenſible heat introduced, we may aſk how long it will be neceſſary to raiſe it all in vapour? Surely another quarter of an hour ſhould be ſufficient; but this is far from being the caſe.

121 Experiments by Dr Black on the converſion of water into vapour.

Dr Black made ſome experiments upon this ſubject in conjunction with another gentleman. Having the opportunity of what is called a kitchen-table or a thick plate of caſt iron, one end of which was made ſenſibly red-hot, they ſet upon this ſome iron veſſels with circular flat bottoms, of about four inches diameter, and which contained a quantity of water. The temperature of the water was noted, as alſo when it began to boil; and when the whole of it was boiled away, it was found, that when ſet on the table its temperature had been 54°; in four minutes it began to boil, and in that ſpace of time received 158° degrees of heat. Had the evaporation, therefore, depended merely on the quantity of ſenſible heat introduced, it ought to have been diſſipated entirely in a ſingle minute more. It was, however, 18 minutes in diſſipating; and therefore had received 807 degrees of heat before it was all evaporated. All this time, therefore, while the water continued to boil, it was receiving a great quantity of heat, which muſt have been flowing equally faſt out of it; for the veſſel was no hotter, and the iron plate continued equally hot, the whole time. The veſſels were of different ſhapes, ſome of them cylindrical, ſome conical, others widening upwards; one of the deſigns of the experiment being to ſhow how far the evaporation was retarded by the particular form of the veſſels. By ſuſpending a thermometer in the mouth of one of the evaporating veſſels, the heat of the ſteam was found to be exactly 212°; ſo that as the great quantity of heat abſorbed was found neither to have remained in the water, nor to have been carried away by the ſteam in a ſenſible manner, we have nothing left to ſuppoſe, but that it flew off as one of the component parts of the ſteam in a latent ſtate.

2. In an experiment to ſhow the fixedneſs of the boiling point of water, Dr Black incloſed ſome of that fluid in a ſtrong vial having a thermometer in it, and ſtopped cloſe with a cork. By the application of heat he hoped now to be able to raiſe the thermometer ſome degrees above the boiling point, which would be the natural conſequence of the confinement of the ſteam. When this was done, he pulled out the cork, and ſuppoſed that the water would now all fly out in vapour: but in this he was totally diſappointed; a ſudden and very tumultuous boiling enſued, which threw out ſome of the water; but though ſome quantity of ſteam likewiſe iſſued, the quantity of water was not conſiderably diminiſhed. The vial had been heated to 20° above the boiling point, but almoſt inſtantly cooled down to 212°, when the cork was taken out.

3. Mr Watt, in making ſome experiments on the force of ſteam, had occaſion to uſe Papin's digeſter, with a pipe proceeding from its ſide; the orifice of which was ſhut with a valve preſſed down by one end of a lever. Thus he heated ſteam to 400° of Fahrenheit; after which, having ſuddenly ſtruck off the lever, a quantity of ſteam flew out with conſiderable noiſe, and with ſuch violence as to make an impreſſion on the ceiling of the room; but this noiſe gradually diminiſhed, and after ten minutes it ceaſed entirely; and upon opening the machine, he found the greateſt part of the water ſtill remaining.

122 Boiling point of water *in vacuo* determined by Mr Boyle.

4. The change of ſenſible into latent heat in the formation of vapour, appears ſtill more evident in the boiling of water *in vacuo*. Mr Boyle took a quantity of water which had been previouſly boiled to purge it of its air, and put it whilſt hot under the receiver of an air-pump. In conſequence of this it began again to boil, and continued boiling till it was only lukewarm, and it ſoon arrived at this temperature; ſo that in this caſe alſo the heat had diſappeared during the converſion of the fluid into vapour.

123 And by Mr Robinſon of Glaſgow.

Others have repeated the experiment, as Boerhaave, Muſchenbroek; and Robinſon, who lectures on chemiſtry in Glaſgow, ſays that the heat diminiſhes very faſt till it comes to 90° or 95°, which ſeems to be the boiling point of water *in vacuo*. As a conſiderable part of the heat thus diſappears, and is to be diſcovered neither in the water nor in the vapour, we muſt conclude that it enters the latter as part of its compoſition.

5. Thus alſo we may underſtand ſome curious experiments made by Dr Cullen upon ether and other volatile

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latile fluids. He employed ſome perſons to make experiments upon the cold produced by evaporation; and willing to repeat them himſelf *in vacuo*, he put ſome of the moſt volatile liquors under the receiver of an air-pump. One of theſe was ether. It was contained in a glaſs, in which there was alſo placed ſome water. When the air was extracted, the ether began to boil, and to be converted into vapour, till it became ſo very cold that it froze the water contained in the veſſel, though the temperature of the room was about 50°. Here therefore there was a quantity of heat which diſappeared all of a ſudden; which it is plain could not be owing to its having any communication with that of the atmoſphere or other cold bodies, as they could not render it colder than they were themſelves. Ether therefore is to be conſidered as a fluid ſo volatile, that were it not for the preſſure of the atmoſphere it would be perpetually in the ſtate of vapour.

124 Dr Cullen's experiments on cold produced by evaporation.

125 Heat expelled in great quantity by the condenſation of vapour.

6. That this heat which enters into the vapour is not deſtroyed, but remains in a latent ſtate, is eaſily proved; for we find that a great quantity of heat is expelled from vapour when it is condenſed again to form the body it compoſed originally. This is eaſily aſcertained by obſerving the quantity of heat communicated to the water in the refrigeratory of a ſtill by any given quantity of liquid which comes over. Thus, if the refrigeratory contain 100 pounds of water, and the diſtillation be continued till only one pound has come over, ſuppoſing the water in the refrigeratory to have received 8° of heat; it is plain, that if the whole of the quantity thus received could be thrown into one pound of water, the latter would be heated to 800°; which is ſufficient to make an equal ſpace of iron red-hot. But that this quantity of heat is received by the water in the refrigeratory has appeared from ſeveral experiments, which ſhow that water, by being converted into vapour, abſorbs between 800° and 900° of heat.

126 Mr Watt's experiments on the evaporation of fluids *in vacuo*.

On this principle we may explain ſome curious experiments made by Mr Watt with regard to the evaporation of fluids *in vacuo*. That gentleman had formed a deſign of converting water into ſteam with leſs expence of fuel, which he imagined might be done by removing the preſſure of the air from the water, which he thought would thus require a much ſmaller quantity of fuel to convert it into vapour. Dr Black, however, perceiving that only the ſmall quantity of ſenſible heat the ſteam poſſeſſed could thus be carried off, informed him beforehand that his project would not be found attended with the advantages he imagined. The experiment, however, was made in the following manner: A ſtill was procured of tinned iron, the body of which reſembled that of a retort, with a veſſel ſerving as a condenſer; the whole apparatus being cloſe, excepting a little hole in the extremity of the condenſing veſſel. He firſt exhauſted this veſſel of air by holding the condenſer over the retort, in which ſome boiling water was contained, until it was entirely converted into ſteam. He then ſuddenly ſtopped the little hole, and removed the veſſels from the fire; when, after they were cooled, there was a pretty perfect vacuum formed by the condenſation of the ſteam. The retort was then put on the fire, and turned ſo that the pipe and condenſing veſſel ſhould hang downward; and plunging them into cold water, heat was applied to the ſtill till the water boiled, as could be known by the noiſe. It was kept boiling, till a quantity of ſteam was puſhed over and condenſed with a very gentle heat, the ſtill feeling little warmer than his hand. After a certain quantity had been diſtilled, the apparatus was removed, and he had noted the heat of the water in the refrigeratory; but though the ſteam all along came over with ſo gentle a heat, he found the quantity communicated to the water in the refrigeratory to be ſurpriſingly great, not leſs than 1000°; ſo that it would have been more than ſufficient to heat the quantity of liquor which came over red-hot.

127 Ignition a conſtant and ſteady effect of heat.

IV. *Ignition*, or the cauſing bodies to ſhine or emit light in the dark. This may be conſidered as a ſpecies of inflammation, and ſhall therefore be explained under that head: here we ſhall only obſerve, that ignition is a more ſteady and conſtant effect of heat than either the production of fluidity or vapour; and appears not only to be the ſame degree with regard to any particular body, but the ſame with regard to all kinds of matter. Dr Martin imagines, that a red-hot piece of iron is hotter than a red-hot piece of ſtone; but if you put into a crucible an hundred different kinds of matter, as metals, glaſs, &c. that are capable of bearing a red heat, they will all begin to appear luminous about the ſame time, and their brightneſs will increaſe equally as their heat increaſes. But it is difficult to know at what point this begins, as we have no way of aſcertaining the beginning or loweſt degree of ignition but by the effect it produces on our ſight, and we cannot be ſure that we perceive the loweſt degree of light; for we know that other animals ſee objects with ſuch light as appears perfect darkneſs to us. Sir Iſaac Newton's method of determining this has been already mentioned.

128 All ignited bodies equally hot.

129 Metals may become vaſtly hotter after they are brought into fuſion.

Dr Boerhaave entertained a notion, that ſome metals, after being once brought into a ſtate of fuſion, could be made no hotter; and propoſes the poſſibility of this as a queſtion, "Whether the heat of metals can be increaſed after they are melted?" There is not, however, the leaſt doubt but that their heat may be vaſtly increaſed after they are melted; and we know certainly that ſuch as are of eaſy fuſion may be heated to a vaſtly greater degree after being melted; and why may not thoſe requiring ſtronger heats be the ſame? We are ſure that this is the caſe with ſilver, which, after being melted, may be brought to ſuch a heat as to become too dazzling for the eye to bear it. If Boerhaave's opinion were juſt, it would be impoſſible to caſt any metal into moulds, becauſe it muſt loſe a little heat in being removed from the fire and in entering the mould; nor would they receive a proper impreſſion if they did not contain a greater quantity of heat than was neceſſary for their fuſion.

130 Ignition an univerſal effect of fire.

Ignition appears to be univerſal; and all bodies capable of ſupporting it without being converted into an elaſtic vapour that cannot be confined, are affected the ſame way. Water, which in its ordinary ſtate ſeems very little capable of enduring this heat, may be confined in ſtrong veſſels ſo as to become capable of melting lead, which is more than half way betwixt a red heat and that of boiling water. Experiments with the colipile ſhow alſo that it can be made red-hot; for when the ſteam paſſes through burning fuel, it can-

131 Water may be made ſufficiently hot to melt lead.

not

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not miſs of being made red hot. Dr Black has alſo frequently ſeen the vapour of water heated by throwing it into the aſh-pit of a furnace, ſo as to produce a very large and tranſparent flame in riſing up through the vent. There is reaſon therefore to conclude, that ignition is one of the more general effects of heat, only that ſome bodies are incapable of it until they be reduced to a ſtate of vapour.

132
Difference betwixt ignition and inflammation.

V. The laſt of the effects of heat here to be taken notice of is *inflammation*. It differs from ignition in this, that the bodies ſubject to the latter gradually grow cooler as ſoon as they are taken out of the fire, without undergoing any conſiderable change; while thoſe ſubject to inflammation become continually hotter and hotter, communicating a vaſt quantity of heat to others, and undergoing a kind of decompoſition themſelves, inſomuch, that by this means they have beeen thought to be reduced to their conſtitnent principles or elements.

133
Inflammation decompounds but does not deſtroy bodies.

Some ſubſtances indeed ſeem to be an exception to this, as in the open air they burn totally away, without leaving any reſiduum or producing any ſoot. Theſe are ſpirit of wine, ſulphur, and eſpecially inflammable air; which laſt, by a proper mixture with dephlogiſticated air, may be ſo totally conſumed, that ſcarce a fiftieth part of the two will remain. On a careful examination of theſe ſubſtances, however, we find that there is by no means a total conſumption, or indeed, properly ſpeaking, any conſumption at all, at leaſt if we meaſure the quantity of matter by the weight of the ſubſtance employed.

134
Spirit of wine yields a great quantity of water by being burned.

Thus, if we are at pains to collect the vapour of burning ſpirit of wine, we will find, that an aqueous dew is collected, which ſometimes equals the ſpirit of wine itſelf in weight. With regard to ſulphur, the caſe is ſtill more evident; for the vapour of this, when collected, not only equals but greatly exceeds the weight of the ſulphur employed; and on burning dephlogiſticated and inflammable air together, as much water is found to be produced as nearly equals the weight of both airs.

135
Water produced by the deflagration of dephlogiſticated and inflammable air.

In like manner, when we collect the aſhes, water, ſoot, and oil, procured by burning any of the common inflammable ſubſtances, we will find, that they in general exceed the weight of the matter employed. The great waſte of bodies by fire, therefore, is owing to the diſſipation of the volatile principles they contain, which are carried off and rendered inviſible by being mixed with the atmoſphere.

136
Of the exiſtence of phlogiſton.

The proceſs of inflammation has long been explained from the preſence of a ſubſtance called *Phlogiſton* in thoſe bodies which are ſubject to it, and which is ſuppoſed to be the ſame in all bodies belonging to this claſs; the differences between them ariſing from the principles with which it is combined.

137
Denied by M. Lavoiſier.

This doctrine, which was firſt introduced by Stahl, has given occaſion to ſuch various and diſcordant theories, that the exiſtence of phlogiſton has been lately denied altogether by M. Lavoiſier, who brought in a new method of ſolving the phenomena of fire, heat, and ignition, without any aſſiſtance from this principle.

138
Arguments againſt it drawn from the increaſed weight of metals by calcination.

The foundation of M. Lavoiſier's doctrine is the increaſe of weight in metals by calcination. This increaſe he finds to be preciſely, or very nearly ſo, proportionable to the decreaſe of weight in the air in which they are calcined. His theory, therefore, is, that in the act of calcination, the pure part of the air, which he calls the *acidifying* or *oxygenous* principle, unites with the metal, and converts it into a calx.

139
His theory of inflammation.

In like manner, in ſubſtances truly inflammable, the heat and flame are ſuppoſed to proceed from the union of the pure air, or the oxygenous principle, with the ſubſtance, and converting it into thoſe principles which are found to remain after inflammation. Thus the increaſed weight of the ſubſtance is eaſily accounted for; while the inflammation, in his opinion, is nothing more than a combination of the inflammable body itſelf with pure air, which has an attraction for it: and in confirmation of that it is urged, that when combuſtion is performed in empyreal or dephlogiſticated air, the whole of the latter is abſorbed; but in common atmoſpherical air only one-fourth, being the quantity of pure air contained in it.

140
Arguments for the non-exiſtence of phlogiſton, from the reduction of the calces of perfect metals without addition.

Other arguments in favour of this opinion are, that the calces of the perfect metals may be reduced without addition by the mere emiſſion of the oxygenous principle, (dephlogiſticated air); by an union with which they aſſume the form of a calx. Thus he evades a very ſtrong argument uſed by the oppoſite party; who adduced, as a proof of the exiſtence of phlogiſton, the uſe of charcoal in the reduction of metals to their proper form.

141
Diſpute betwixt Lavoiſier and Prieſtley.

A diſpute indeed took place betwixt M. Lavoiſier and Dr Prieſtley concerning the reduction of the whole of a mercurial calx formed by an union with the nitrous acid without addition; the Doctor maintaining that the whole could not be reduced by mere heat, but that a very perceptible quantity was always loſt: but on a thorough examination of the ſubject, the truth ſeemed rather to lie on M. Lavoiſier's ſide. See AEROLOGY.

142
Dr Lubbock's theory.

Another theory, ſomewhat ſimilar to that of Lavoiſier's, has been publiſhed by Dr Lubbock, in an Inaugural Diſſertation in 1784. In this he ſuppoſes two kinds of matter to exiſt in the univerſe; one he calls the *principium proprium*, the other the *principium ſorbile*; and it is this latter, which, according to our author, is the principle of mutability, or which by being united in various proportions with the other, forms bodies of all the different kinds we ſee in nature. It is this principle, therefore, which he ſuppoſes to be abſorbed in the calcination of metals, and not empyreal air, as M. Lavoiſier ſuppoſes; and he contends, that this ſame principle extends throughout the whole ſyſtem of nature, even to the utmoſt celeſtial bounds.

143
Diſputes concerning phlogiſton now entirely decided.

It would exceed the limits of this treatiſe to give an account of the various theories which have been invented, and the arguments uſed for and againſt them; nor indeed is there any occaſion for doing ſo, as late experiments have reduced the diſpute into a much narrower compaſs than before, and furniſhed the moſt deciſive arguments in favour of the exiſtence of phlogiſton.

144
Objections againſt the exiſtence of phlogiſton from its inviſibility and ſuppoſed want of gravity.

The greateſt objection to the belief of this principle was, that it could neither be ſeen nor felt by our ſenſes directly, nor diſcover itſelf indirectly by the weight it communicated to the bodies with which it was united; on the contrary, the latter always became lighter in proportion to the quantity they contained: ſo that it was imagined, inſtead of being poſſeſſed of any ſpecific gravity [illegible], to be a principle of poſitive levity, [illegible] heat or light may be reaſonably ſuppoſed. This objection, however, is now intirely removed; [illegible] phlogiſton in the abſtract is found

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found to be no ſubtile principle capable of eluding our reſearches, but one very common, and eaſily met with, being no other than common charcoal.

145 Common charcoal and phlogiſton the ſame.

In the laſt edition of this work, under the article PHLOGISTON, it was ſhown, that inflammable air, deprived of its elaſticity, and combined with metallic ſubſtances, is really their phlogiſton; and that in the inflammable bodies commonly uſed, what we call their phlogiſton, is really their oil; and that which exiſts in charcoal, and cannot be driven off by diſtillation, is part of the empyreumatic or burnt oil of the ſubject which adheres ſo obſtinately. A ſimilar doctrine ſoon after appeared in the Philoſophical Tranſactions for 1782, and the identity of phlogiſton and inflammable air was clearly proved by Mr Kirwan.

146 Deciſive proofs of this identity given by Dr Prieſtley.

Still, however, it was inſiſted by the French philoſophers and others, that no *facts* had been adduced againſt M. Lavoiſier, nor any deciſive proofs appeared of the exiſtence of phlogiſton as a ſubſtance *per ſe*. Facts of this kind, however, have now been diſcovered by Dr Prieſtley, and are related under the articles AEROLOGY, CHARCOAL, PHLOGISTON, &c. It is ſufficient at preſent to mention, that he

147 Spirit of wine and metals convertible into charcoal.

has been able to convert the pureſt ſpirit of wine, and one of the hardeſt metals, viz. copper, as well as ſeveral others, into a ſubſtance entirely reſembling charcoal; that by means of the heat of a burning glaſs in vacuo, he has diſſipated this metallic charcoal, as well as the common kind, *entirely* into inflam-

148 Charcoal entirely diſſipated by heat into inflammable air.

mable air, with the aſſiſtance only of a little water, which ſeems neceſſary to make it aſſume the aerial form, and perhaps is the true ſolvent of it; and by a combination with the element of heat, with the aid of the charcoal, is enabled to reſiſt condenſation in the common way.* This inflammable air, when abſorbed by metallic calces, again reduces them to their metallic

149 Metallic calces reduced by inflammable air.

form: ſo that here is one fact by which the phlogiſton not only appears to our ſenſes, but we are able to aſcertain its quantity with the utmoſt preciſion. Nor can it here be any objection, that the reduced metal is lighter than the calx; for this only proves that the

150 Why metals are lighter in their metallic than in their calcined ſtate.

metallic earth, while a calx, is united to a heavy ingredient (the baſis of dephlogiſticated air), and in the latter to a light one, viz. charcoal, the baſis of inflammable air.

* See *Elaſtic Vapour.*

Another caſe in which the exiſtence of phlogiſton is made equally evident to our ſenſes, and where no ſuch objection can occur, is related under the article AEROLOGY, n° 112. It is there ſhown, that "by the

151 Dephlogiſticated air converted into aerial acid by charcoal.

loſs of one grain of charcoal of copper (formed by the union of ſpirit of wine with the metal), and which like common charcoal was conſumed without having any reſiduum, he reduced four ounce-meaſures of dephlogiſticated air till only one-ninth remained unabſorbed by water; and, again, with the loſs of one grain and a half of charcoal, ſix and an half meaſures of dephlogiſticated air were reduced till five and an half meaſures were pure fixed air."—Here, then, is an abſolute and undeniable evidence, that fixed air is compoſed of dephlogiſticated air, and charcoal or phlogiſton, and elementary fire. There were no other ingredients preſent, and the charcoal muſt either have been annihilated or diſpoſed of in the manner juſt mentioned: but the ſuperior weight of the fixed air evidently ſhows that ſome ingredient had been added to the dephlogiſticated air; and which increaſe was more than we can ſuppoſe to ariſe from the condenſation of the dephlogiſticated air during the operation, for this ſometimes amounted to no more than one-thirtieth part.

152 Objections drawn from the total combuſtion of dephlogiſticated air in ſome caſes.

The ſtrongeſt objection which can be made againſt the doctrine of phlogiſton may be drawn from the total conſumption of pure air in certain caſes of combuſtion, for inſtance, in that of phoſphorus, inflammable air, and iron. It muſt be obſerved, however, that in no caſe whatever is the air totally conſumed; and in that of inflammable air water is produced by the union of the baſis of the latter, that is charcoal, with the baſis of dephlogiſticated air, the oxygenous principle of M. Lavoiſier, and which appears to be one of the component parts of WATER. In the caſe of phoſphorus, the latter is converted into an acid; and in all probability a quantity of water is alſo produced, by which part of it is converted into cryſtalline

153 Little phlogiſton expelled from iron by being burnt in dephlogiſticated air.

flowers. The caſe of the iron, therefore, alone remains to be conſidered. Dr Prieſtley's experiments on this ſubject are related at length under the article AEROLOGY, n° 67 *et ſeq.* In them the iron burnt briſkly in dephlogiſticated air, which, according to the common theory, ſhould have indicated the expulſion of a great quantity of phlogiſton; yet the whole reſiduum, of which the fixed air, produced by the ſuppoſed union of the phlogiſton or principle of inflammability, was only a part, ſcarce amounted ſometimes to one-fourteenth of the air originally employed.

154 The objection inconcluſive.

The argument, however, inſtead of contradicting the exiſtence of phlogiſton, only ſhows, that in ſome caſes the diſſipation of a very ſmall quantity of phlogiſton is neceſſary to inflammation; or that the aerial principle may combine with the iron in its metallic ſtate. In this caſe only a very little quantity of the phlogiſton of the iron was diſſipated; for it was

155 Iron is not reduced to a calx by burning in dephlogiſticated air.

not reduced to a calx, but to that kind of ſcoriæ which flies off in ſcales by beating the metal when red-hot with an hammer. A deciſive proof of this was had by uniting iron thus combined with the baſis of dephlogiſticated air with inflammable air. By this the metal was indeed reduced to perfect

156 Water produced in the reduction of it by inflammable air.

iron again; but water was produced at the ſame time from the union of the baſis of the two airs, that of the inflammable air being capable of furniſhing a ſuperfluous quantity, which united with the other into the form of a fluid.

157 Heat produced in the combuſtion of inflammable bodies derived from the air.

The exiſtence of phlogiſton being thus proved, and its nature aſcertained, we may now proceed to determine the queſtion, Whether the great quantity of heat produced by the combuſtion of inflammable bodies proceeds from the bodies themſelves, or from the air which muſt be admitted to them in order to make them burn? That the heat in this caſe proceeds from the atmoſphere is evident; becauſe in all caſes of combuſtion there is a certain diminution undoubtedly takes place by means of the converſion of the dephlogiſticated part of the atmoſphere into fixed air. It is proved, under the article *ELASTIC Vapours*, that elementary fire is the univerſal cauſe of elaſticity in fluids. By uniting a certain quantity of it with any ſubſtance, the latter at length aſſumes an aerial or vaporous form; and it is this vapour alone which is inflammable*. Different vapours no doubt contain different quantities of theſe ingredients; but in all caſes the baſis of the dephlogiſticated part of the atmoſphere

* See the article *Flame.*

General Effects of Heat.

must unite with the phlogiston of the inflammable body, or with something else, so that a decomposition may ensue: and it is this decomposition which produces the heat and light; for then the fire contained in the
158 atmosphere having no longer any thing to absorb it, must appear in its proper form. But in those cases where there is a great quantity of phlogiston, and consequently much fixed air produced, the latter absorbs so much heat in a latent state, that the quantity communicated to surrounding bodies must be greatly diminished; and if an excess of this ingredient, not only fixed air, but the phlogisticated kind and gross smoke be also produced, this diminishes the heat still farther by the great absorption, and will even destroy it altogether. The remedy for this is either to diminish the quantity of phlogiston, or to augment the quantity of air; which, by furnishing a greater quan-
159 tity of dephlogisticated basis, affords an opportunity for the evolution of a greater quantity of heat. On the other hand, when the quantity of air is too great, the phlogistic matter cannot combine with the basis of the pure air in sufficient quantity to effect a decomposition; and therefore the heat is absorbed in a latent state, and the fire goes out.

Too much phlogiston prevents the heat from being intense.

Too great a quantity of air has the same effect.

From this theory, which is farther illustrated under the articles FIRE, FLAME, HEAT, PHLOGISTON, &c. we may not only have a rational idea of the manner in which inflammation is generally accomplished, but see
160 why a fire may be put out both by too great a quantity of fuel, and by too great a quantity of air. We may also see why the solar beams and electric fluid, which contain no phlogistic matter, excite a much more powerful heat than any we can raise in our hottest furnaces. The difference between ignition and inflammation will now likewise appear; such bodies as are capable only of ignition containing little or no phlogiston, but inflammable bodies a great deal.

Why the solar heat and that of electricity are so intense.

161 The following table shows the most remarkable degrees of heat from the congelation of mercury to that of Mr Wedgewood's hottest furnace.

Table of the various degrees of heat.

Mercury freezes at - -	40
Weak spirit of wine - -	32
Brandy at - - -	10
Cold produced by snow and salt mixed	0
Strong wine freezes at -	20
Vinegar freezes at - -	27
Water freezes at - -	32
Temperature of spring and autumn	50
Ordinary summer weather -	65
Sultry heat - - -	75
Heat of human blood -	97 to 100
Feverish heat - - -	108
Bees wax melts - - -	142
Serum coagulates - - -	156
Spirit of wine boils - -	174
Water boils - - -	212
Tin melts - - -	408
Bismuth melts - -	460
Oil of vitriol boils - -	550
Oil of turpentine boils -	561
Lead melts - -	585
Quicksilver and linseed-oil boil -	600
Iron begins to shine in the dark -	635
Iron shines briskly in the dark -	750
Iron shines in the twilight -	884
Iron red-hot from a common fire	1050
Red heat fully visible in day light according to Mr Wedgewood -	1077
Heat by which his enamel colours are burnt on - - -	1857
Brass melts - - -	3807
Swedish copper melts - -	4587
Fine silver melts - -	4717
Fine gold melts - -	5237
Least welding heat of iron -	12777
Greatest ditto - -	13427
Greatest heat of a common smith's forge - - -	17327
Cast iron melts - -	17977
Greatest heat of Wedgewood's small air-furnace - - -	21877
Extremity of the scale of his thermometer - - -	32277

Elective Attraction.

SECT. II. *Of the Doctrine of Elective Attraction, and of the different Objects of Chemistry.*

162
BEFORE we proceed to give a general theory of the changes which happen upon the mixtures of different bodies together, or exposing them singly to heat, we must observe, that all depend on certain qualities in bodies, by which some of them are apt to join together, and to remain united while they have an opportunity. The cause of these qualities is totally unknown; and therefore philosophers, after the example of Sir Isaac Newton, have expressed the apparent effect of this unknown cause by the word *attraction*. From them the word has been adopted by the chemists, and is now generally used in speaking of the phenomena which are observed in the mixture of different substances; but to distinguish it from other kinds, it is usually called *Elective*.

Chemical attraction.

This attraction is not equally strong between all substances; in consequence of which, if any body is compounded of two others, and another is presented to it which has a greater attraction for one of the component parts than they have for one another, the substance will be *decompounded*. A new compound is then formed by the union of that third substance with one of the component parts or *elements* (if we please to call them so) of the first. If the attraction between the body superadded and either of the component parts of the other is not so strong as that between themselves, no decomposition will ensue; or if the third substance is attracted by both the others, a new composition will take place by the union of all the three. 163

The objects of chemistry, as we have already observed, are so various, that an enumeration of them all is impossible. To ease the mind, therefore, when speaking of them, and render more useful any thing that is said or wrote on chemistry, it is necessary to divide them into different classes, comprehending in each class those bodies which have the greatest resemblance to one another, and to which one common rule applies pretty generally.—The division formerly used, was that of vegetables, animals, and minerals; but this has been thought improper, as there are many substances in each of those kingdoms which differ very widely from one another, and which are by no means subject to the same laws. The most approved method,

Objects of chemistry how classed.

Salts. thod, at present, of arranging the objects of chemistry, is into salts, earths, metals, inflammable substances, waters, animal and vegetable substances.

Sect. III. *Salts.*

164 Salts. Salts are either *fusible*, that is, capable of abiding the fire, and melting in a strong heat, without being dissipated; or *volatile*, that is, being dispersed in vapour with a small heat. Their other properties are, that they are soluble in water: not inflammable, unless by certain additions; and give a sensation of taste when applied to the tongue.

The most general characteristic of salts is, that they are all soluble in water, though some of them with much more difficulty than others. Most of them have likewise the property of forming themselves, in certain circumstances, into solid transparent masses of regular figures, different according to the different salt made use of, and which are termed *crystals* of that salt. In this state they always contain a quantity of water; and therefore the utmost degree of purity in which a salt can be procured, is when it has been well crystallized, and the crystals are freed of their superfluous moisture by a gentle heat. They generally appear then in the form of a white powder.

165 Phenomena attending their solution. In the solution of salts in water, the first thing observable is, that the water parts with the air contained in it; which immediately rises to the top in the form of bubbles. This, however, is most remarkable when the salt is in the dry form we have just now mentioned, because there is always a quantity of air entangled among the interstices of the powder, which rises along with the rest; and this discharge of air is sometimes so great, as to be mistaken for an effervescence. From this, however, it is essentially different. See Effervescence.

Another thing observable in the solution of salts is, that a considerable change happens in the temperature of the water in which they are dissolved; the mixture becoming either a good deal warmer or colder than either the salt or the water were before. In general, however, there is an increase of cold, and scarce any salt produces heat, except when it has been made very dry, and deprived of that moisture which it naturally requires; and thus the heating of salts by being mixed with water may be explained on the same principle with the heat produced by quicklime. See Quicklime.

After salt has been dissolved in a certain quantity by water, no more of that salt will be taken up unless the water is heated; and as long as the heat continues to increase, the salt will be dissolved. When the water boils, at which time it has attained its greatest heat, and will take up no more salt, it is then said to be *saturated* with that salt. This, however, does not prevent it from taking up a certain quantity of another salt, and after that perhaps of a third, or fourth, without letting go any of the first which it had dissolved. How far this property of water extends, has not yet been ascertained by experiments.

To the above rule there is only one exception known as yet; namely, common sea-salt: for water dissolves it in the very same quantity when cold as when boiling hot. It has been said by some, that all deliquescent salts, or those which grow moist on being exposed to the air, had the same property: but this is found to be a mistake. Salts.

This property of solubility, which all the salts possess in common, renders them easily miscible together; and the property by which most of them shoot into crystals, renders those easily separable again which have no particular attraction for one another. This is likewise rendered still more easy by their requiring different proportions of water, and different degrees of heat, to suspend them; for by this they crystallize at different times, and we have not the trouble of picking the crystals of one out among those of the other. 166 Mixture and separation of salts.

The manner in which the solution of salts in water is effected, is equally unaccountable with most of the other operations of nature. Sir Isaac Newton supposed that the particles of water got between those of the salt, and arranged them all at an equal distance from one another: and from this he also accounts for the regular figures they assume on passing into a crystalline form; because, having been once arranged in an orderly manner, they could not come together in disorder, unless something was to disturb the water in which they were suspended; and if any such disturbance is given, we find the crystals are by no means so regular as otherwise they would have proved. Others have thought that these figures depend on a certain *polarity* in the very small particles into which the salt is resolved when in a state of solution. These things, however, are merely conjectural; neither is it a matter of any consequence to a chemist whether they are right or wrong. 167 Hypothesis concerning the solution of salts.

Though solution is that operation which salts undergo the most easily, and which should seem to affect them the least of any, a repetition of it proves nevertheless very injurious to them, especially if it is followed by quick evaporation; and the salt, instead of being crystallized, is dried with a pretty strong heat. Newman relates, that a pound of sea-salt was reduced, by 13 solutions and exsiccations, to half an ounce; and even that was mostly earth. Where solution is required, therefore, it ought always to be done in close vessels, in which also the subsequent evaporation should be performed, (see Evaporation); and in all cases where crystallization is practicable, it ought to be preferred to violent exsiccation. 168 Salts destructible by repeated solutions.

The two great divisions of salts are into acids and alkalies. The former of these are known by their peculiar taste, which is called *acid* or *sour*. They are not found in a solid form; neither are any of them, except the acids of vitriol, of tartar, of phosphorus, and of borax, capable of being reduced to solidity. The others, when highly concentrated, that is, brought to the utmost degree of strength of which they are capable, always become an invisible vapour, permanently elastic, until it comes in contact with water, or some other substance with which they are capable of uniting. For such acids the name of *salts* seems less proper, as we can scarcely say that a *vapour*, which is already much more fluid than water, can be *dissolved* in that element. 169 Acids.

The acids are divided into the mineral, the vegetable, and the animal; expressing their different origin, or where they are most commonly to be found. The mineral acids are commonly reckoned three; the vi-

vitriolic, the nitrous, and the marine. To this the acid of borax ought to be added; but its weakneſs makes it much leſs taken notice of as an acid than the others. A Swediſh chemiſt, however, Mr Scheele, hath lately added ſeveral others, which are afterwards taken notice of.

The vegetable kingdom affords only two diſtinct ſpecies of acids, at leaſt without the aſſiſtance of ſome chemical operation. The one appears fluid, and when concentrated to the utmoſt degree becomes an inviſible vapour. This is produced from fermented liquors, under the name of *vinegar*. An acid ſimilar to this, and which is thought not to be eſſentially different from it, is extracted from moſt vegetables by diſtillation with a ſtrong fire. The other is likewiſe a conſequence of fermentation; and cruſts on the bottom and ſides of caſks in which wine is put to depurate itſelf. In its crude ſtate it is called *tartar*; and when afterwards purified, is called the *cream*, or cryſtals, of tartar. As for the various acids produced in the different chemical proceſſes to be afterwards related, we forbear to mention them at preſent, it being juſtly ſuſpected that ſome of them are artificial.

The animal acids, which have hitherto been diſcovered, are only two; the acid of ants, and that of urine, which is alſo the acid of phoſphorus. The firſt of theſe is volatile; and conſequently muſt be ſuppoſed a vapour when in its ſtrongeſt ſtate: the other is exceedingly fixed; and will rather melt into glaſs than riſe in vapours. Beſides theſe, it is ſaid an acid is contained in blood, in waſps, bees, &c.: but no experiments have as yet been made on theſe to determine this matter with any degree of preciſion.

170 Alkalies.

The alkalies are of two kinds; fixed and volatile. The fixed kind are ſubdivided into two; the vegetable, and mineral or foſſil alkali. The vegetable is ſo called, becauſe it is procured from the aſhes of burnt vegetables; the foſſile, becauſe it is found native in ſome places of the earth, and is the baſis of ſea-ſalt, which in ſome places is dug out of mines in vaſt quantity. They are called *fixed*, becauſe they endure a very intenſe degree of heat without being diſſipated in vapour, ſo as even to form a part of the compoſition of glaſs. The volatile alkali is generally obtained by diſtillation from animal ſubſtances. In its pure ſtate this alkali is perfectly inviſible; but affects the ſenſe of ſmelling to ſuch a degree, as not to be approached with ſafety.

171 Different action of alkalies and acids.

The acids and alkalies are generally thought to be entirely oppoſite in their natures to one another. Some, however, imagine them to be extremely ſimilar, and to be as it were parts of one ſubſtance violently taken from each other. Certain it is, that when ſeparated, they appear as oppoſite to one another as heat and cold. Their oppoſite action indeed very much reſembles that of heat and cold, even when applied to the tongue; for the alkali has a hot, bitter, burning taſte, while the acid, if not conſiderably concentrated, always gives a ſenſation of coldneſs. In their action too upon animal ſubſtances, the alkali diſſolves, and reduces the part to a mucilage; while the acid, if not very much concentrated, tends to preſerve it uncorrupted.

172 Neutral ſalts.

If an alkaline ſalt, and moderately ſtrong acid in a liquid ſtate, be mixed together, they will immediately unite; and, provided the alkali has not been deprived of its fixed air, their union will be attended with a very conſiderable effervеſcence: (ſee AEROLOGY.) If the alkali has been deprived of air, no effervеſcence will enſue, but they will quietly mix together; but if a due proportion of each has been added, the liquor will neither have the properties of an acid nor an alkali, but will be what is called *neutral*. The bringing the liquor into this ſtate, is called *ſaturating* the acid or alkali, or combining them to the point of ſaturation.

If the liquor after ſuch a ſaturation be gently evaporated, a ſaline maſs will be left, which is neither an acid nor an alkali, but a new compound formed by the union of the two, and which is called a *perfect neutral ſalt*. The epithet *perfect* is given it, to make a diſtinction between the ſalts formed by the union of an acid and an alkali, and thoſe formed by the union of acids, with earthy or metallic ſubſtances; for theſe will likewiſe unite with acids, and ſome of the compounds will cryſtallize into regular figures; but, becauſe of their weaker union with theſe ſubſtances, the ſalts reſulting from combinations of this kind are called *imperfect*.

173 Vegetable colours changed by acids and alkalies.

All acids, the volatile ſulphureous one excepted, change the blue infuſions of vegetables, ſuch as violets, to a red; and alkalies, as well as ſome of the imperfect neutrals, change them to green. This is the niceſt teſt of an acid or alkali abounding in any ſubſtance, and ſeems the moſt proper method of determining whether a ſolution intended to be neutral really is ſo or not.

174 Differences in the degrees of attraction between acids and alkalies

Though between every acid and alkali there is a very ſtrong attraction, yet this is far from being the ſame in all; neither is it the ſame between the ſame acid and alkali in different circumſtances of the acid. When the acids are in a liquid ſtate, and as free as poſſible of inflammable matter, between which and the nitrous and vitriolic acids there is a very ſtrong attraction, the vitriolic will expel any of the reſt from an alkaline baſis, and take its place. Thus, if you combine the acid of ſea-ſalt, or marine acid, to the point of ſaturation, with the foſſil alkali, a neutral ſalt will be formed, which has every property of common ſalt: but, if you pour on a certain proportion of the vitriolic acid, the acid of ſea-ſalt will immediately be expelled; and the liquor, upon being evaporated, will contain not the neutral ſalt formed by an union of the marine acid with the alkali, but another conſiſting of the vitriolic acid joined with that alkali, and which has quite different properties from the former.

When the acids and alkalies are applied to one another in a liquid ſtate, the vitriolic acid always ſhows itſelf to be the moſt powerful; but when applied in a ſolid form, and urged with a violent heat, the caſe is very much altered. Thus, the acid of borax, commonly called *ſal ſedativus*, is ſo weak as to be diſengaged from its baſis by every acid applied in a liquid form, that of tartar alone excepted; but if even the vitriolic acid combined with an alkali be mixed with this weak acid, then exſiccated, and at laſt urged with a vehement fire, the vitriolic acid will be diſengaged from its baſis, and riſe in vapours, leaving the weaker acid in poſſeſſion of the alkali. The ſame thing happens on adding the phoſphorine or urinous acid,

acid, or the acid of arſenic, &c. to combinations of the vitriolic or other acids with alkaline ſalts.—When the acids are in a liquid ſtate, therefore the moſt powerful is the vitriolic; next the nitrous; then the marine; then vinegar; acid of ants; and laſtly the ſal ſedativus and tartar, which ſeem to be nearly equal in this reſpect.—If they are applied in a ſolid form, the moſt powerful are the ſal ſedativus and phoſphorine acid; then the vitriolic, nitrous, marine, and vegetable acids.

When they are reduced to vapour, the caſe is exceedingly different; for then the marine acid appears to be the moſt powerful, and the vitriolic the leaſt ſo of any. It is impoſſible, however, to preſerve the vitriolic acid in the form of vapour, without combining it with a certain quantity of inflammable matter, which muſt neceſſarily deſtroy its ſtrength. Dr Prieſtley found, that the marine acid, when reduced to vapour, was capable of diſuniting the nitrous acid from a fixed alkali.

Though the vitriolic acid ſometimes aſſumes a ſolid form, it is by no means eaſy to reduce it to this ſtate by mere concentration, without the aſſiſtance of nitrous acid. Baldaſart, however, pretends that he diſcovered, in the neighbourhood of a volcano, a pure and icy oil of vitriol, from which nothing could be precipitated by alkaline ſalts; though there is certainly very great reaſon to doubt the accuracy of this obſervation. Of late the nitrous acid has alſo been found capable of aſſuming a ſolid form. This was firſt obſerved by M. Bernhard in diſtilling a very large quantity of the acid. At that time he perceived a white ſalt adhering to the inſide of the receiver, which on examination proved to be the acid of nitre in a concrete form; being extremely corroſive, emitting red vapours copiouſly on being expoſed to the air, and at length totally evaporating in it. Its ſpecific gravity, however, was far inferior to that of the glacial oil of vitriol.

175 Acids unite with phlogiſton.

The acids have the property of uniting themſelves to many other ſubſtances beſides fixed alkalies, and forming neutral compounds with them. Of theſe the chief is the principle of inflammability or phlogiſton. In the vitriolic, nitrous, and phoſphorine acids, the attraction for this principle is very ſtrong; ſo great, that the two former will even leave a fixed alkali to unite with it. In the marine acid it is leſs perceptible; in the liquid vegetable or animal acid ſtill leſs; and in the acid of tartar, and ſal ſedativus, not at all.

176 With metals and earth.

Beſides this, all acids will diſſolve metallic and earthy ſubſtances: with theſe, however, they do not in general unite ſo firmly with alkaline ſalts; nor do they unite ſo ſtrongly with metals as with earths.

177 Elective attractions.

In general, therefore, we may expect, that after having diſſolved a metal in any acid whatever, if we add an earthy ſubſtance to that ſolution, the acid will quit the metal, which it had before diſſolved, to unite with the earth. In this caſe the ſolution will not be clear as before, but will remain muddy, and a quantity of powder will fall to the bottom. This powder is the metalline ſubſtance itſelf, but deprived of one of its component parts; and in this caſe it is ſaid to *precipitate* in the form of a *calx*.

If to this new ſolution of the earthy ſubſtance in an acid liquor, a volatile alkaline ſalt, not deprived of its fixed air, is added, the acid will quit the earth, and unite with the alkaline ſalt. The earth thus diſengaged will again *precipitate*, and lie at the bottom in fine powder, while the volatile alkali and acid remain combined together, and the liquor again becomes clear.

The attraction between volatile alkalies and acids is conſiderably leſs than between fixed alkalies and the ſame acids. If, therefore, a fixed alkali be now added to the liquor, the volatile alkali will be ſeparated, and the acid will unite with the fixed alkali. The volatile alkali indeed, being perfectly ſoluble in water, cannot precipitate, but will diſcover its ſeparation by the pungent ſmell of the mixture; and upon evaporating the liquor, the volatile alkali will be diſſipated, and a ſaline maſs, conſiſting of the acid and fixed alkali, will remain.

178 Detonation of nitre.

Laſtly, If the acid employed was the nitrous, which has a ſtrong attraction for the principle of inflammability, if the ſaline maſs be mixed with a proper quantity of inflammable matter, and expoſed to a ſtrong heat, the acid will leave the alkali with vaſt rapidity, combine with the inflammable matter, and be deſtroyed in flame in a moment, leaving the alkali quite pure.

179 Exceptions to the above rules.

Though the abovementioned effects generally happen, yet we are not to expect that they will invariably prove the ſame whatever acid is made uſe of; or even that they will be the ſame in all poſſible variety of circumſtances in which the ſame acid can be uſed.—The acid of tartar is one exception, where the general rule is in a manner reverſed; for this acid will quit a fixed alkali for an earth, eſpecially if calcined, and even for iron. If lead, mercury or ſilver, are diſſolved in the nitrous acid, and a ſmall quantity of the marine acid is added, it will ſeparate the ſtronger nitrous acid, and fall to the bottom with the metals in form of a white powder.—The vitriolic acid, by itſelf, has a greater attraction for earthy ſubſtances than for metals; and greater ſtill for fixed alkaline ſalts than for either of theſe: but if quickſilver is diſſolved in the nitrous acid, and this ſolution is poured into a combination of vitriolic acid with fixed alkali, the vitriolic acid will quit the alkali to unite with the quickſilver. Yet quickſilver by itſelf cannot eaſily be united with this acid. The reaſon of all theſe anomalies, however, is fully explained in the following ſection.

§ 1. *Of the Operations of Solution and Precipitation.*

THE chemical ſolution of ſolid bodies in acid or other menſtrua, is a phenomenon which, though our familiarity with it has now taken off our ſurpriſe, muſt undoubtedly have occaſioned the greateſt admiration and aſtoniſhment in thoſe who firſt obſerved it. It would far exceed the limits of this treatiſe to ſpeak particularly of all the various circumſtances attending the ſolution of different ſubſtances in every poſſible menſtruum. The following are the moſt remarkable, collected from Mr Bergman's Diſſertion on Metallic Precipitates.

180 Phenomena attending the ſolution of a metal.

1. On putting a ſmall piece of metal into any acid, it is diſſolved ſometimes with violence, ſometimes gently, according to the nature of the menſtruum and of the metal to be diſſolved.

2. The nitrous acid is the moſt powerful in its action

Solution and Precipitation.

tion upon metallic substances, when unassisted by heat. So great indeed is the violence with which this acid sometimes acts, that the metal, instead of being dissolved, separates instantaneously from it in the form of a calx or powder scarce soluble in any menstruum, at the same time that the heat, effervescence, and noxious vapours issuing from the mixture, render it absolutely necessary to moderate the action of the menstruum, either by dilution or cold, or both. In other cases, however, as when put to gold or platina, the nitrous acid has no effect until it be united with the marine, when the mixture acts upon those metals, which neither of the acids singly would touch.

181 Nitrous acid the most violent in its operation.

182 Vitriolic acid acts more weakly.

3. The action of the vitriolic acid, though in the higest degree of concentration, is more weak. It does not readily attack silver or mercury unless assisted by a boiling heat, nor will even that be sufficient to make it act upon gold or platina.

183 Marine acid generally more weak than either, except when dephlogisticated.

4. The action of marine acid, unless on some particular substances, is still more weak; but when dephlogisticated, or deprived of part of the phlogiston essential to its constitution as an acid, it acts much more powerfully, and dissolves all the metals completely.

184 The rest of the acids much weaker still.

5. The other acids, as those of fluor, borax, with such as are obtained from the animal and vegetable kingdoms, are much inferior in their powers as solvents, unless in very few instances.

185 Different degrees of solubility in metals.

6. Metals vary very much in their degrees of solubility; some yielding to almost every menstruum, and others, as has been already observed, being scarce acted upon by the most powerful.

186 Solution sometimes promoted by abstracting a certain proportion of phlogiston.

7. Zinc and iron are of the former kind, and gold and silver of the latter, eluding the marine; and gold, unless in one particular case, viz. when assisted by heat in a close vessel, the action of the nitrious acid also. These metals, however, which in their perfect state resist the action of the most powerful menstrua, may be dissolved much more readily when deprived of a certain quantity of their inflammable principle. But though the separation of this principle in some degree renders metals more soluble, the abstraction of too much of it, particularly in the case of iron and tin, renders these metals almost entirely insoluble. Manganese is the most remarkable instance of this power of the phlogistic principle, in depriving metals of their solubility by its absence, or restoring it to them by its presence; for this substance, when reduced to blackness, cannot be dissolved by any acid without the addition of some inflammable matter; but when by the addition of phlogiston it has become white, may be dissolved in any acid.

187 But is totally prevented by taking away too much: exemplified in manganese.

188 Solution of metals attended with an effervescence.

8. The dissolution of metals by acids, even to their very last particle, is attended by a visible effervescence: this is more perceptible according to the quickness of the solution; but more obscure, and scarcely to be seen at all, when the solution proceeds slowly.

189 Various kinds of elastic fluids extricated.

9. The elastic fluids extricated by these solutions are various, according to the nature of the acid and of the metal employed. With the nitrous, the fluid produced is commonly that called *nitrous air*; with vitriolic and marine acids the produce is sometimes inflammable air, sometimes otherwise, according to the nature of the metal acted upon.

10. Heat in a greater or smaller degree is always produced during the dissolution of metals; and the degree of it is in proportion to the quantity of the matter and the quickness of the solution; and hence, in small quantities of metal, and when the solution proceeds very slowly, the temperature of the mass is scarcely altered.

190 Heat produced during the dissolution of metals.

11. The calces of metals either yield no air at all, or only the aerial acid, unless when urged by a violent heat almost to ignition; when, by means of vitriolic or nitrous acid, they yield a quantity of pure air, after other elastic fluids, such as vitriolic, nitrous, or phlogisticated air. None of the dephlogisticated air is usually produced by the marine acid in conjunction with metallic calces.

191 Little air can be obtained from metals when calcined.

192 Various colours of metallic calces.

12. The solutions of some metals are coloured, others are not. The colour of the former is only that which is proper to the calx, but rendered more vivid by the moisture. Thus solutions of gold and platina are yellow; those of copper, blue or green; solutions of nickel of a bright green; but those of cobalt are red, although the calx is black. We may observe that even this red colour may be heightened to blackness. Iron moderately calcined is green; but this rarely continues upon further dephlogistication. The white calces of silver, lead, tin, bismuth, arsenic, antimony, and manganese, are dissolved without colour; but solutions of lead, tin, and antimony, are somewhat yellow, unless sufficiently diluted. Mercury, however, forms a singular exception to this rule; for the orange-coloured calx of this metal forms a colourless solution. The metals yielding coloured solutions are gold, platina, copper, iron, tin, nickel, and cobalt; the rest, if properly depurated, give no tinge. A solution of silver is sometimes of a blue or green colour at first, although there be no copper present; the vitriolic acid becomes blue with copper; the nitrons may be made either blue or green at pleasure; the marine varies according to the quantity of water with which it is diluted. Manganese, when too much dephlogisticated, renders both the vitriolic and marine acids purple.

193 Bergman's account of the cause of chemical solution.

With regard to the cause of chemical solutions, our author observes, that though attraction must be looked upon as the fundamental cause, yet we may also lay it down as a maxim, that no metal can be taken up by an acid, and at the same time preserve the whole quantity of phlogiston which was necessary to it in its metallic state. A certain proportion of the principle of inflammability therefore may be considered as an obstacle which must be removed before a solution can take place. Thus, of all the acids, the nitrons attracts phlogiston the most powerfully, and separates it even from the vitriolic. A proof of this may be had by boiling sulphur slowly in concentrated nitrous acid. At length all its phlogiston may be separated, and the vitriolic acid will remain, deprived of its principle of inflammability. The extraordinary solvent powers of this acid, therefore, is conformed to the peculiarity of its nature in this respect. For this menstruum dissolves metals for solution with the greatest ease, most commonly without any assistance from external heat; which in some instances would be hurtful, by separating too much of phlogiston, as appears in the case of iron, tin, and antimony; all of which may be so far dephlogisticated by the nitrons acid, as to be rendered extremely difficult of solution: for this reason it is very often necessary, as has already been observed, to temper the activity

194 Solution impeded by too great a quantity of phlogiston.

159 Sulphur dephlogisticated by nitrous acid.

196 Calces of some metals prepared by nitrous acid almost insoluble ever afterwards.

Solution and precipitation.

activity of this menſtruum by water. The vitriolic acid requires a boiling heat before it can act upon ſilver or mercury. The reaſon of this is, that by means

197 Why the vitriolic acid cannot act on lead, ſilver, &c. without a boiling heat.

of the heat, the watery part of the menſtruum is diminiſhed, its power is thereby increaſed, and the connection of the metallic earths with the inflammable principle diminiſhed. Marine acid, which contains phlogiſton as one of its conſtituent principles, muſt neceſſarily have little or no effect on thoſe metals which retain their principle of inflammability very obſtinately. But its watery part being diminiſhed by boiling, it aſſumes an aerial form, and powerfully attracts a lar-

198 Why marine acid acts on ſome metals and not on others.

ger quantity of phlogiſton than before; ſo that in a vaporous ſtate it will diſſolve metals, particularly ſilver and mercury, which in its liquid form it would ſcarce be brought to touch. When dephlogiſticated as much as poſſible, it attracts phlogiſton with prodigious avidity, diſſolving all metals by its attraction for their phlogiſton, and, uniting the inflammable principle to itſelf, reſumes the ordinary form of marine acid. When dephlogiſticated by means of nitrous acid in aqua regis, it diſſolves gold and platina. On the ſame principles may we account for its inferiority in power to

199
the other acids.

Why ſome metals are more ſoluble than others.

It has already been obſerved that the metals differ much in their degrees of ſolubility, which is owing to the various, degrees of force with which they retain their phlogiſton. Thoſe called perfect metals effectually reſiſt calcination in the dry way. In this operation, the fire on the one hand, the great cauſe of the volatility of bodies, ſtrenuouſly endeavours to expel the phlogiſton; on the other hand, the baſis of the dephlogiſticated part of the atmoſphere (the acidifying principle of M. Lavoiſier, and the *principium ſorbile* of Dr Lubbock) attracts the calx ſtrongly. Experience, however, ſhows, that theſe two forces united, cannot decompoſe gold, ſilver, or platina to any conſiderable degree. All the other metals yield to theſe forces when united, but not ſingly. Iron and zinc retain their inflammable principle ſo ſlightly, that any acid immediately acts upon them; but if the other metals be properly prepared for ſolution by being calcined to a

200
certain degree, the acid will immediately take them up.

Why nitrous acid precipitates a ſolution of tin or antimony.

Any further privation, however, would be injurious, and precipitate what was before diſſolved. Thus the nitrous acid, when added to a ſolution of tin or antimony in marine acid, by its extraordinary attraction for phlogiſton carries off ſuch a quantity of it, that

201
the calces of the metals are immediately precipitated.

Different kinds of air produced during the diſſolution of metals.

The various elaſtic fluids which reſemble air, and which are produced in plenty during the diſſolution of metals, may be reduced to the following, *viz.* thoſe extricated by the vitriolic, nitrous, and marine acids, fluor acid, vinegar, alkaline ſalts, and hepar ſulphuris.

Pure vitriolic acid expoſed to a violent heat, is in-

202
deed reſolved into vapours, but of ſuch a nature, that

Pure vitriolic acid cannot be reduced into an aerial form but by a combination with phlogiſton.

when the heat is gone, they condenſe again into an acid liquor of the ſame nature as before. But if any ſubſtance be added which contains phlogiſton in a ſeparable ſtate, an elaſtic fluid is produced by means of fire, which is ſcarcely condenſible by the moſt extreme cold, unleſs it comes in contact with water. This is called the volatile ſulphureous acid, or vitriolic acid air, which may be readily abſorbed by water. In this caſe the bond of union betwixt it and the phlogiſton is ſo weak, that the latter ſoon flies off totally, and common vitriolic acid is regenerated.

Solution and Precipitation.

The nitrous acid undergoes a ſimilar change in a more obvious manner. Let a piece of ſilver, for in- 203

Nitrous acid more obviouſly changed.

ſtance be put into a dilute nitrous acid, and the ſurface of the metal will inſtantly be covered with innumerable bubbles, which ariſing to the top of the liquor, there burſt; and if collected, are found to be nitrous air. The nitrous acid ſaturates itſelf with phlogiſton more completely than the vitriolic; therefore the elaſtic fluid produced, or nitrous air, does not unite with water, and ſcarce retains any veſtige of an acid nature. The vitriolic acid, however, differs from the nitrous in this reſpect, that the phlogiſton is abſorbed by the latter even beyond the point neceſſary to obliterate its acid nature. In proof of this, our author adduces the decompoſition of hepatic by means of nitrous air.

204 Why nitrous air does not unite with water.

205 Phenomena exhibited by the marine acid.

The marine acid exhibits different phenomena. It naturally contains phlogiſton, and therefore can by its means be reſolved into a kind of air ſomewhat ſimilar to that produced by the vitriolic acid when artificially united to the ſame principle, and which has the ſame property, *viz.* that of remaining permanently elaſtic as long as it is kept from the contact of water. But as the acid we ſpeak of naturally contains phlogiſton, there is no neceſſity of adding more to produce this effect. In the mean time, the marine as well as nitrous air, when in its expanded ſtate, attracts phlogiſton, and that with wonderful avidity. 206

Of the dephlogiſticated marine acid.

When the marine acid is dephlogiſticated, it yields another elaſtic fluid of a reddiſh brown colour, having an odour like that of warm aqua regia. This does not unite with water, or only in very ſmall quantity: and by the addition of a proper proportion of phlogiſton may be reduced again to common marine acid. It is ſaid that the marine acid may be dephlogiſticated by lead as well as by mangancſe, the nitrous acid, and arſenic. 207

Of the fluor acid.

The fluor acid abounds with phlogiſton, and therefore may, without any adventitious matter, be reduced to an elaſtic fluid. This air is eaſily diſtinguiſhed from all others by its corroſion of glaſs whilſt hot. 208

Why vinegar may be reduced into air without addition.

Vinegar alſo contains phlogiſton; and for that reaſon, when well dephlegmated, may be reduced without addition into a permanently elaſtic fluid, called acetous air.

All theſe fluids ſeem to be nothing elſe, according to Mr Bergman, than the acids themſelves expanded by phlogiſton. "Perhaps (ſays he) the matter of 209

Heat and not phlogiſton the principle of elaſticity.

heat alſo enters their compoſition." The experiments lately made on theſe ſubjects, however, have put it beyond all doubt, that the expanſive principle is not phlogiſton but heat; nevertheleſs, it ſeems highly probable, that theſe elaſtic fluids do really conſiſt of the acid united to phlogiſton, and expanded by heat. This is alſo the caſe with the cauſtic volatile alkali, now called alkaline air. 210

Sulphur exiſts in hepatic air.

In the hepatic air, it has been ſhown by Mr Bergman, that ſulphur exiſts which contains phlogiſton; and there is little reaſon to doubt that the expanſive power here is the ſame as in other caſes. See HEPATIC AIR.

The heat generated during the ſolution of metals is by Mr Bergman ſuppoſed to be owing to the matter

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of heat which had been fixed in the metals; but it may with much more reason be supposed to proceed from the acid. Dr Black has demonstrated, that heat is universally the principle of fluidity; and all fluids, whether acid or not, are found to contain a great quantity of it. It is not probable that solids, even the most inflammable, contain an equal quantity; for it is always observed, that bodies in becoming fluid absorb heat, and throw it out again on becoming solid. Acids in all probability contain a much greater quantity than what is necessary to their fluidity; for we see that the nitrous acid, when poured upon snow, parts with as much heat as is necessary to dissolve the snow, at the same time that it still retains its fluidity. The case is not so with common salt, which is a solid: for though, in a mixture of salt and snow, the latter absorbs as much heat from the salt as is necessary for its own liquefaction; yet the salt could not be held in solution by a liquid of this temperature, were it not that an additional quantity is perpetually absorbed from the adjacent bodies, particularly the atmosphere. But were it possible to prevent this adventitious increase of heat, there is not the least reason to believe that the salt would be dissolved; for the strongest brine, when reduced to the temperature of 0 of Fahrenheit, is decomposed, the salt falling to the bottom in powder, and the water being converted into ice. Add to this also, that the cold produced by spirit of nitre and snow is much more intense than that produced by common salt and snow; which undoubtedly shows, that a solid does not readily part with as much heat as a fluid, and consequently cannot be supposed to contain as much. The solution of metals in acids also demonstrates, that the solid substance has not parted with heat, but absorbed it; for as soon as the solution becomes solid again, *i. e.* when it crystallizes, the temperature becomes higher than before.

211 Heat in solution most probably proceeds from the solvent liquor.

212 Solid bodies do not part with so much heat as fluids.

213 Why little or no elastic fluid is obtained from metallic calces.

The calces of metals have not that quantity of phlogiston that is necessary for their metallic state, but yet are not entirely destitute of it; therefore, in their solution, scarce any elastic fluid is generated, unless the fire be continued after exsiccation. Such as contain aerial acid, discharge it immediately in the same form as they had received it. It is remarkable, that Dr Priestley mentions a calx of lead, which, with the acid of phosphorous, produced an inflammable air. By means of the nitrous acid and evaporation to dryness, a pure air is produced. Sometimes a small portion of vitriolic acid air is obtained by means of a proper degree of fire from vitriolic acid, but a far greater quantity of pure air.

214 Metallic solutions contain a calx of the metal with various degrees of phlogiston.

The solutions made by the menstrua abovementioned, contain a metallic calx intimately united with the acid, the quantity of phlogiston left being various according to the difference of the menstrua and of the temperature; but the performance of the operation either with or without intense heat, frequently occasions a remarkable difference. That metals are less calcined by the marine than by the nitrous acid, appears from pouring concentrated nitrous acid on tin or antimony; but the difference, if it actually does take place, is less visible in other metals.

Some modern chemists have denied this calcination of metals by solution. They have insisted, that the perfect metals ought to be excepted, as they do not yield to the most intense fire. On this subject, however, it may be observed, 1. That during their solution nitrous air is always generated, and that of a very perfect kind, which cannot happen without phlogiston; but in this case there is nothing present which can yield phlogiston except the metals. Therefore, 2. The metals, when precipitated from their menstrua by fixed alkalis, both with respect to their external appearance and internal properties, appear to be calcined. Thus the precipitate of gold refuses to unite with mercury, and may be dissolved by marine acid and other simple menstrua, and that without the production of any elastic fluid. 3. Glass may be stained by these calces; but no metal in its perfect state can be taken up by glass.

215 Reasons for believing that metals are calcined by phlogiston.

216 Why the calces of the perfect metals may be reduced without addition.

The common objection is, that the calces of the perfect metals may be reduced by heat alone without the addition of charcoal. Many theories have been invented to solve this phenomenon. Some have supposed, that the matter of heat and light are the same with the phlogiston, and that thus the calces are reduced in the same manner as by charcoal or other substances usually termed *phlogistic*. But in this case we ought to find the calces of the imperfect metals also reduced by a long continuance of heat, as well as the more perfect; which, however, has never yet been known to take place. Some, among whose number is Dr Lewis, have imagined, that the porosity of the vessels, particularly those made of earthen ware, may be such as to admit the passage of phlogistic vapours through them; and he instances the revival of globules of lead in the middle of pieces of glass upwards of an inch in thickness, and that where there was not the least appearance of a crack. But from an experiment of Mr Kirwan's to be afterwards related, it is much more probable that the reduction is effected by means of the phlogiston contained in one part of the calx attracted by another; by which means the latter is reduced to a perfect metal, while the former becomes somewhat more dephlogisticated. In consequence of this it appears, that the calx of the perfect metals is never totally reduced: for if the operation be performed in a glass retort, the bottom of it is always stained; which indicates the existence of a calx, in however little quantity.

217 Difficulty concerning the amalgamation of silver solved by Bergman.

The following fact, Mr Bergman says, has been proposed to him as an inextricable dilemma. "Silver cannot amalgamate with mercury except when in its metallic state, yet both salited and nitrated silver are taken up by mercury; it is therefore not calcined by the acids, but adheres to them in its metallic form." This, however, may be easily solved in the following manner. It is well known that the calx of copper, dissolved in the vitriolic acid, is precipitated in its metallic form on the addition of iron, and that by means of a double elective attraction; for the iron, dissolving in the acid, would form an inflammable air by its phlogiston, were not the copper present which takes it up, and thereby becomes insoluble as long as it retains it; but mercury has a stronger attraction for acids than silver: if therefore salited or nitrated silver be triturated with mercury, the silver must be precipitated in a metallic state, and the mercury be calcined by being dissolved. This also takes place, provided there be moisture sufficient to suffer the elective attractions

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tions to operate. The ſuperabundant mercury greedily takes up the comminuted ſilver precipitate; and the *arbores Dianæ* are nothing more than ſuch an amalgam cryſtallized. But although the acids cannot take up any metal while it retains its full proportion of phlogiſton, various metallic ſalts are able to effect that ſolution. Thus nitrated or ſalited mercury, boiled in water together with the crude metal, can take up a certain portion of it without dephlogiſtication; and the latter of theſe ſalts, even in the *via ſicca*, becomes a mercurius dulcis, which contains at the ſame time a crude and a calcined mercury.

218
Phlogiſton the cauſe of colour in metallic ſolutions.

Perfect ſolutions ſhould in general be tranſparent; but ſome, as has been already mentioned, are diſtinguiſhed by a peculiar colour. That phlogiſton is the chief cauſe of colour appears from hence, that the black clax of mangan eſe tinges vitriolic acid of a red colour; but on the addition of ſugar the tinge is entirely deſtroyed. Nitrous acid is rendered blue by copper; but when the metal is added in conſiderable quantity, it becomes of a very deep green. The marine acid, which dephlogiſticates the copper leſs, is yet made green; but by dephlegmation may be ſo condenſed as to become brown. Mr Bergman has ſometimes ſeen a ſolution of ſilver green, without the preſence of the ſmalleſt particle of copper. This depends on the abſorption of nitrous air: for let ſmoking nitrous acid be diluted, on the addition of a certain quantity of water it will be of a deep green; by a greater, blue; and upon a ſtill greater, becomes limpid. By means of the water, the nitrous air is extended to a greater ſpace; and this attenuation gradually increaſed varies the colours. Hence we ſee why nitrous acid is made green by a large quantity of copper.

219
Attraction of phlogiſton the cauſe of cauſticity.

Metals dephlogiſticated by acid ſolvents powerfully attract phlogiſton; nay, nitrated ſilver and mercury, and ſalited antimony, corrode animal ſubſtances, in order, as our author ſuppoſes, to extract it. "This metallic cauſticity (ſays he), which is only to be moderated by phlogiſton, ought to be carefully diſtinguſhed from the acid cauſticity, which is repreſſed by alkalies, and the alkaline, which is mitigated by acids. Colours vary according to the quantity of phlogiſton preſent; and ſome experiments ſhow, that by a ſufficient quantity all colour is entirely deſtroyed.

220
Phenomena attending the precipitation of metals by alkaline ſalts.

All metals may be precipitated by alkaline ſalts; which, by their ſuperior power of attraction, ſeparate them from their menſtrua; but their difference with regard to their nature and preparation alters the nature of the precipitate. With the cauſtic fixed alkali the calces fall almoſt entirely pure, but loaded with water. The weight is found to be increaſed by the water, and perhaps (ſays Mr Bergman) by the matter of heat; but yet leſs than by the aerial acid. With the aerated fixed alkali, by means of a double decompoſition, the aerial acid unites to moſt calces The volatile alkali, which naturally contains phlogiſton, ſometimes phlogiſticates the precipitate. It throws down a black or white precipitate of mercury; nay, it makes the orange-coloured precipitate white. Gold receives its fulminating quality from this precipitant, as is afterwards to be explained. The alkali, which is commonly called *phlogiſticated*, generally precipitates metals with an increaſe of weight.

The acids frequently occaſion precipitates, and that for various reaſons. By means of elective attraction, mercury, ſilver, and lead, are taken from the nitrous acid by the addition of the marine or vitriolic. Theſe acids form with the metals new compounds which are difficult of ſolution in water; they are therefore precipitated in greater or leſſer quantity according to circumſtances. The nitrous acid is capable of decompounding ſalited tin and antimony by dephlogiſticating the calx of the metals too much; for when theſe are too much calcined, they cannot be diſſolved in any menſtruum, as has been already obſerved.

221
Precipitates occaſioned by acids, and why;

222
By the perfect neutral ſalts;

Metallic ſolutions are ſometimes diſturbed by the neutral ſalts formed by an union of alkalies with acids. Thoſe which contain the vitriolic or marine acids decompoſe ſolutions of ſilver, mercury, or lead, in nitrous acid, and precipitate the metals. By forming a triple combination, the vegetable as well as the volatile alkali, though ſaturated with vitriolic, nitrous, or marine acid, precipitate platina from aqua regia; but when the baſis is mineral alkali, the ſalt has no power of this kind. Some metallic ſalts can decompoſe others, and precipitate their baſes; which may happen whether the acid be different in the two ſalts or not. Solution of gold affords an example of each of theſe caſes. This is precipitated by martial vitriol; the reaſon of which will appear from conſidering the nature of the precipitate: for this, when well waſhed and dried, not only ſhows many ſhining gold-coloured particles, but alſo unites with mercury by trituration, diſſolves in aqua regia, but not in marine acid alone, together with other circumſtances which evince a complete reſuſcitation of the gold. Martial vitrol, in its ordinary ſtate, contains phlogiſton, but very looſely adhering; ſo that the clax of gold may eaſily take it from the ſolution to ſupply the loſs it had ſuſtained during the ſolution. That this is the true foundation of the proceſs, appears alſo from the following circumſtances, that the weight of the gold is exactly recovered, and that dephlogiſticated vitriol will not precipitate this metal. The reaſon that the ſurrounding aqua regia leaves this precipitate untouched is, that the menſtruum is diluted and weakened by a large quantity of water; for upon boiling it gently, ſo as to expel part of the water, the menſtruum recovers its ſolvent power, and takes up the precipitate again.

223
By a triple combination.

224
Some metallic ſalts decompoſe others.

225
Why ſolution of gold is precipitated by green vitriol;

226
But not by this ſalt when dephlogiſticated.

227
Why ſolution of gold is precipitated by ſolution of tin.

It is ſomewhat more difficult to explain the reaſon why the ſolution of gold in aqua regia ſhould be precipitated by a ſolution of tin in the ſame menſtruum. Here Mr Bergman firſt ſuppoſed that the the tin had attracted a ſuperabundance of acid, and taken it from the gold; which being therefore deſtitute of its proper quantity, muſt fall to the bottom: but on employing a ſolution containing a ſuperabundant aqua regia, the ſame precipitation took place. The cauſe is therefore not in the menſtruum. On examining the precipitate itſelf, we find nothing like the metallic ſplendor of gold, but that it entirely reſembles a calx. It is eaſily found by its weight, indeed, that it cannot conſiſt entirely of gold; and in fact chemical examination ſhows that it conſiſts partly of tin. It cannot be diſſolved by the marine acid alone, but is eaſily taken up by the addition of a little nitrous acid. It ſcarcely unites with mercury by trituration. Theſe properties ſeem to indicate, that the gold has ſo far received phlogiſton

228
This precipitate conſiſts partly of tin.

Solution and Precipitation.

giston as to resist the marine acid until it receive the assistance of the nitrous; but its earthy appearance, and difficulty of uniting with mercury, evince that it is not in its complete metallic form. The following therefore, according to our author, seems to be the most easy and rational explanation. The solution of tin necessary for this operation must retain as much phlogiston as it possibly can, in a consistence with solubility. This is dropped into a solution of gold very much diluted; by which means the phlogiston remaining in the tin is more loosened, and of consequence more easily attracted by the gold calx, which is thereby brought to a state approximating to completion, so that it can no longer be retained by the menstruum; and the same happens to the tin, by means of the dephlogistication; they must both therefore fall to the bottom mixed intimately with one another. It is probable, says he, that in this case it is the tin which prevents the matter from uniting with mercury.

229
Precipitation of metals by one another, owing to a double elective attraction.

The metals precipitate one another after a certain order, which is the same in all acid menstrua. This precipitation is occasioned by a double elective attraction; for the metal to be precipitated exists in the solution in a calcined state; but being reduced by the phlogiston of the precipitant falls to the bottom, while at the same time the precipitant becomes soluble by calcination: but if the precipitant has been calcined so that a part of it being insoluble is mixed with the precipitate, the metallic splendor is wanting, and it puts on an earthy appearance. A pure precipitate is of the same weight with the metal before solution. The mixed precipitates are less frequently met with, yet gold precipitated by tin exhibits one of that kind.

230
Variations in the order in which the metals precipitate one another.

Though the order in which the metals precipitate one another is constant and never inverted, yet there are many anomalous circumstances which occur in the matter. Thus zinc constantly prevails over iron; iron over lead; lead over tin; tin over copper; copper over silver; silver over mercury, &c. yet it sometimes happens, that a metal which, according to the general rule, precipitates another in its metallic state from one menstruum, precipitates it from another in form of a calx, and not at all from a third. Thus zinc precipitates iron from marine acid in its metallic state, but from the nitrous only in form of a calx. Tin is precipitated by lead from the marine acid in its metallic state, but is not thrown down from the nitrous acid; and from the acetous is precipitated even by iron and zinc in form of a calx; solution of lead in vinegar is not precipitated by iron.

231
Mineral alkali why preferred as a precipitant by Mr Bergman.

In Mr Bergman's experiments on this subject he employed the mineral alkali, as the degree of its saturation with fixed air was more constant. When he had occasion for a caustic alkali, he prepared it by a small quantity of burned lime kept in a close bottle; and the goodness of it was proved by its occasioning no precipitation in lime water.

232
How he prepared his caustic alkali.

Phlogisticated alkali, or that by which Prussian blue is prepared, was also made use of. With these he made the following observations.

233
Various precipitates of gold.

Gold dissolved in aqua regia is precipitated by caustic alkali almost black; by the aerated, yellow, as well as by the phlogisticated, unless some iron be present, which frequently happens; but the whole of the gold is scarce ever precipitated, so that the weight cannot be ascertained.

234
Mineral alkalies precipitate platina imperfectly.

Neither the caustic nor aerated mineral alkali precipitate one half of platina dissolved in aqua regia; the precipitate is of an orange colour, which on drying becomes brown. An over-proportion of alkali redissolves the precipitate, and the liquor becomes more dark; nay, the precipitation is so imperfect, that the matter seems to be dissolved even by neutral salts. The phlogisticated alkali does not precipitate the depurated solution, nor even make it turbid, but heightens the colour in the same manner as an excess of alkali.

235
Precipitates of silver.

Solution of silver in nitrous acid lets fall a white precipitate by the aerated alkali; brown by the caustic, and of an obscure yellow. By the nitrous and marine acids it lets fall a white precipitate, which with the former consists of more distinct particles, which grow black more slowly with the light of the sun.

236
Of mercury.

Salited mercury lets fall a red precipitate, or rather one of a ferruginous colour, by aerated alkali; but of a more yellowish or orange colour by the caustic. Nitrated mercury prepared without heat, yields a ferruginous precipitate with mineral alkali; a black with caustic: and when prepared with heat, it yields to caustic alkali an orange or reddish yellow precipitate. By phlogisticated alkali it is precipitated from all acids of a white colour; but turns of a brownish yellow when dry. Salited mercury is very sparingly precipitated by this alkali. The precipitate by phlogisticated alkali is again dissolved, if too much of the precipitant be made use of.—Corrosive sublimate must be very cautiously precipitated by caustic, as well as aerated fixed alkali; for the part separated may again be dissolved by a large quantity of water. When too much alkali is used, a new compound arises of a peculiar nature.

237
Precipitates of lead.

Solution of lead in spirit of nitre is precipitated down white by aerated, caustic, or phlogisticated alkali. By using too much alkali, the precipitate by the phlogisticated kind is dissolved with a brownish yellow colour. Vitriol of lead and solution of lead in marine acid are precipitated white.

238
Of copper;

Blue solution of copper in spirit of nitre is precipitated of a bright green by aerated fixed alkali; by the caustic of a greyish brown, which grows reddish by age. By phlogisticated alkali copper is precipitated of a greenish colour, which grows afterwards of a brownish red, and upon exsiccation almost black. The aerial acid takes up a small quantity of copper during the precipitation, which is again deposited by the heat of boiling.

239
Of iron;

Aerated fixed alkali precipitates iron of a green colour from vitriolic and marine acid; but the precipitate becomes of a brownish yellow, especially on exsiccation; with the caustic alkali it approaches more to black. In the precipitation some part is held in solution by the aerial-acid, when the mild alkali is used. With phlogisticated alkali a Prussian blue is formed.

240
Of tin;

Tin is precipitated of a white colour by every alkaline salt, even by the phlogisticated kind; but at length some blue particles appear in the mixture: so that the whole, when collected and dried, appears of a light blue colour. That these blue particles are occasioned by iron appears by calcination; for they become ferru-

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ferruginous, and obey the magnet. Our author has always found a proportion of iron in tin.

241 Precipitates of bismuth; Bismuth is thrown down of a fine white by water and alkalies, particularly the former; phlogisticated alkali throws down a yellow powder, which being mixed with blue particles occasioned by iron, at length appears green. This yellow sediment easily dissolves in nitrous acid.

242 Of nickel; Nickel is precipitated of a whitish green by fixed alkalies; by the phlogisticated alkali of a yellow; and by exsiccation it is condensed into a dark brown mass.

243 Of arsenic; Arsenic dissolved in acids, which prevent too great dephlogistication, may, to a certain degree, be precipitated white by the fixed alkali, even when phlogisticated, but the sediment is found soluble in water; yet nitrous acid, either alone, or joined with the marine, generally dephlogisticates the arsenical acid, which thereby becomes unfit for separation. Arsenic dissolved in marine acid, with the assistance of a little nitrous acid, deposited a white sediment on the addition of a large quantity of phlogisticated alkali. The sediment was mixed with Prussian blue. This was dissolved in water, and freed by frequent filtration from the blue particles; and at length, on evaporating to dryness, yielded a semipellucid mass.

244 Of cobalt; Cobalt dissolved in acids is thrown down by fixed alkali, whether aerated or caustic, of a reddish blue, which grows darker on exsiccation, especially when the former alkali has been used. Phlogisticated alkali throws down a powder of almost the same colour, which, upon exsiccation, becomes of a reddish brown.

245 Of zinc; Zinc is precipitated white by aerated and caustic fixed alkalies, as also by the phlogisticated alkali; but this last becomes of a citron colour on exsiccation: a small portion of aerial acid may easily escape during the precipitation.

246 Of antimony; Antimony is precipitated white by alkalies. When the phlogisticated alkali is used, some blue particles are almost always precipitated at the same time, though the regulus had been prepared without any iron. This operation should be cautiously conducted, lest some part be taken up by the alkaline salt.

247 Of manganese. Manganese procured by reduction from common magnesia nigra, generally renders menstrua brown, and with aerated alkali yields a yellowish brown sediment; with the caustic, one still darker; with the phlogisticated, first a blue, then a white, powder is separated, the mixture of which renders the mass a black green. To obtain a pure and white calx of manganese, we must dissolve in pure vinegar the precipitate thrown down by caustic alkali; for there still remains a quantity of iron which is taken up by the aerial acid. This acetous solution contains little or nothing of iron. That metal may also at first be separated by a small quantity of volatile alkali.

The common solution of the regulus is not perfectly precipitated by the aerated alkali; and upon evaporating the remaining liquor spontaneously to dryness, grains of a metallic splendor, and not unlike copper, are deposited on the glass. The nitrous acid attracts these readily, though they are only partially dissolved by it; but on the addition of zinc, nothing falls besides the manganese, though at first it is a little reddish. With phlogisticated alkali, we obtain a yellow precipitate like pure manganese, provided the solution has deposited the iron when too much dephlogisticated by age. But the new solution yields a precipitate almost like that which is obtained from common regulus. The yellow sediment may be dissolved in water.

248 On the cause of such great variations in the weight of precipitates.

The following is Mr Bergman's table of the quantities of precipitate of different metals, thrown down from various menstrua by the different alkalies. "On comparing the weights (says he), a question occurs concerning the cause of such enormous differences; and it is plain, that this cause must be sought for in the precipitates themselves.—The fixed alkali saturated with aerial acid, when added to the solution, is taken up by the more powerful menstruum; and the weaker is of course expelled, and is absorbed by the calx as it falls, in greater or lesser quantity according to circumstances. That this is actually the case is easily demonstrated:—Let a bottle containing a quantity of nitrous acid be accurately weighed. Let there be put into it, for instance, 132 parts of lead precipitated by aerated alkali; and not only an effervescence will be observed, which continues until the very last particle is dissolved, but when the solution is finished, a deficiency of weight is discovered, which amounts nearly to 21, and which is undoubtedly owing to the extrication of aerial acid. But $132-21=111$; a weight which still considerably exceeds that of the metal. Upon distillation nearly eight of water are discovered. There yet remain therefore three, which by violent heat are increased by seven; for 132 of the calx well calcined yield 110. The whole increment of weight then does not depend on the water and aerial acid. The same thing is evinced by considering the precipitate of lead by the caustic alkali; in which case there can be no aerial acid, nor does any effervescence accompany the solution. If we suppose the quantity of water equal in both cases, yet even on this supposition the whole excess of weight is not accounted for; for $116-8=108$. It is therefore probable, that the matter of heat is attached to the calx (A).—In proof of this opinion, and that caustic alkalies contain the matter of heat, our author adduces several arguments, of which the following is the strongest.—

249 Argument in favour of the weight of precipitates being augmented by the matter of heat.

"Let the heat occasioned by the mixture of any acid and caustic alkali be determined by a thermometer; let then an equal portion of the same menstruum be saturated with a metal; afterwards, on the addition of an equal quantity of caustic alkali, it will be found, either that no heat is generated, or a degree very much less than before.—Some of the matter of heat therefore is taken up and fixed, which also generally makes the colours of the precipitates more obscure; and in distillation with sal-ammoniac, communicates to the volatile alkali the quantity that had been taken away."

250 Insufficient

In this instance also, however, our author seems to have been deceived. It has already been observed, that in all solutions generating heat, it most probably comes from the fluid. Acids contain a quantity sufficient

(A) This increase of weight is with more probability to be ascribed to a remainder of the acid.

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ſcient not only for their own fluidity, but for rendering ſolid bodies fluid alſo. After they have diſſolved the metal, however, this ſuperfluous quantity is employed; and when the cauſtic alkali is added, if in a ſolid form, it is again employed in giving fluidity to the alkali; or if the alkali be already diſſolved, the increaſed quantity of fluid makes the heat extricated leſs perceptible.

"What has been ſaid of lead (continues our author), is alſo true of the other metals, a few excepted, which ſeem to take up little or no aerial acid; ſuch are tin, antimony, gold and platina.—But ſome pre-

251 A quantity of the menſtruum retained by ſome precipitates.

cipitates retain alſo a quantity of the menſtruum. Thus, corroſive mercury, precipitated by aerated alkali, retains a portion of marine acid, which cannot be waſhed off by water; but, by cauſtic alkali, the precipitate may be obtained, either free of the acid altogether, or in a great meaſure. In this caſe, as in many others, the aerial acid ſeems to generate a triple ſalt, ſcarce at all ſoluble. The preſence of the marine

252 Difference in the precipitates of mercury.

acid is eaſily diſcovered by ſolution of ſilver in nitrous acid, if the menſtruum has been pure. Hence we obſerve another difference in mercury precipitated from marine acid, according as we employ the aerated or cauſtic alkali; the latter, well waſhed, and put into volatile alkali, is ſcarcely changed in colour; but the former inſtantly grows white, generating a ſpecies of ſal-alembroth, but containing ſo little marine acid as not to be eaſily ſoluble in water. The calces which retain any of their former menſtruum, generally give over on diſtillation a ſmall portion of ſublimate. The mercurial calx juſt mentioned, expoſed to a ſufficient degree of heat, is partly reduced to crude mercury, partly to mercurius dulcis, by means of its remaining marine acid. This mercurius dulcis did not exiſt in the precipitate; for in that caſe it would be eaſily diſcovered by acids in which it is not ſoluble, and would grow black with cauſtic alkali, neither of which take place, ſo that it muſt be generated during the diſtillation."

253 Advantages to be derived from the examination of metallic precipitates.

Mr Bergman concludes his diſſertation, with an enumeration of the advantages reſulting from the careful examination of metallic precipitates.—Theſe are 1. That thus the theory of the operation will be more perfectly underſtood. 2. We may diſcover the more uſeful and remarkable properties. 3. A foundation is thereby laid for eſſaying in the moiſt way, from the bare knowledge of the weights. "It may be objected (ſays he), that the doctrine of the weights is very fallacious; that they vary in different precipitates; that by imperfect precipitation ſomething remains in the liquor; and that ſometimes extraneous matters remain in them. All this is true; but if the mode of operation be the ſame, the reſults of the experiments will be equally conſtant. Thus, let us ſuppoſe that a certain quantity of metal *a*, precipitated in a certain manner, makes a weight *b*; if that ſame manner be exactly employed, we may fairly conclude, that a quantity of precipitate *nb*, occurring in any caſe, is correſpondent to a quantity of perfect metal *na*; though, in the fundamental experiment, the precipitation is either incomplete, or ſome extraneous matter may be preſent. 4. The nature of metals is thus illuſtrated. Platina, nickel, cobalt, and mangancſe, are ſuppoſed by ſome to derive their origin from a mixture of other metals. But if iron neceſſarily enters into the compoſition of platina, when the latter is diſſolved in aqua regia, it ought to yield a Pruſſian blue on the addition of phlogiſticated alkali; which indeed is the caſe when common platina is employed, but not with that which is well depurated.

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254 Platina is not compoſed partly of iron;

255 Nor regulus of nickel;

256 Cobalt or mangaueſe

257 Quantity of precipitate obtained from manganeſe by phlogiſticated alkali.

In like manner, if iron, adhering very obſtinately to nickel, formed a great part of the latter, the precipitates obtained from it by alkalies could not differ from martial precipitates ſo much as they do in colour, weight, and other properties. The ſame holds true of cobalt and manganeſe. The regulus obtained from the latter contains about 0.08 of iron, which affects the mixture in the following manner. An hundred pounds diſſolved in an acid menſtruum, yields, by treatment with phlogiſticated alkali, a powder conſiſting partly of blue, partly of browniſh yellow particles, equal in weight to 150 pounds; but eight pounds of iron yield 48 of Pruſſian blue, nearly $\frac{1}{3}$ of the whole maſs of precipitate: whence it follows, that 100 parts of pure manganeſe yield to phlogiſticated alkali ſcarcely 111; *i. e.* nearly ſix times leſs than an equal weight of iron.

258 Metals contain different quantities of phlogiſton.

"Laſtly, by this method of examining precipitates, it may perhaps be poſſible to determine the unequal quantities of phlogiſton in different metals; for a given weight of precipitating metal does not yield an equal quantity of precipitate: thus, for inſtance, copper is able to precipitate from nitrous acid four times its weight of ſilver."

259 Table of different precipitates.

100 parts of	Precipitated by	Yielded dry precip.
Gold,	aerated mineral alkali -	106
——	cauſtic - -	110
——	phlogiſticated -	—
——	martial vitriol -	100
Platina,	aerated mineral alkali -	34
——	cauſtic - -	36
——	phlogiſticated -	—
Silver,	aerated mineral alkali -	129
——	cauſtic - -	112
——	phlogiſticated -	145
——	ſalited - -	133
——	vitriolated -	134
Mercury,	aerated mineral alkali -	110
——	cauſtic - -	104
——	phlogiſticated -	—
——	vitriolated - -	119
Lead,	aerated mineral alkali -	132
——	cauſtic - -	116
——	phlogiſticated -	—
——	vitriolated. - -	143
Copper,	aerated mineral alkali -	194
——	cauſtic - -	158
——	phlogiſticated -	530
Iron,	aerated mineral alkali -	225
——	cauſtic - -	170
——	phlogiſticated -	590
Tin,	aerated mineral alkali -	131
——	cauſtic - -	130
——	phlogiſticated -	250
Biſmuth,	aerated mineral alkali -	130
——	cauſtic - -	125
——	phlogiſticated -	180
——	pure water -	113
Nickel,	aerated mineral alkali -	135
——	cauſtic - -	128
——	phlogiſticated -	250
Arſenic,	aerated mineral alkali -	—

Arſenic,

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100 parts of	Precipitated by	Yielded dry precip.
Arsenic,	caustic	—
	phlogisticated	180
Cobalt,	aerated mineral alkali	160
	caustic	140
	phlogisticated	142
Zinc,	aerated mineral alkali	193
	caustic	161
	phlogisticated	495
Antimony	aerated mineral alkali	140
	caustic	138
	phlogisticated	138
Mang.	aerated mineral alkali	180
	caustic	168
	phlogisticated	150

260
Kirwan's definition of chemical attraction.

Mr Kirwan has made a great number of experiments on the attractive powers of the mineral acids to various substances, and greatly illustrated the operations of both solution and precipitation. Chemical attraction, he observes, "is that power by which the invisible particles of different bodies intermix and unite with each other so intimately, as to be inseparable by mere mechanical means." Thus it differs from the attraction of cohesion, as well as from that of magnetism and electricity, as not acting with the indifference observed to take place in these powers, but causing a body already united to another to quit that and unite with a third; whence it is called *elective* attraction. Hence attraction of cohesion often takes place betwixt bodies that have no chemical attraction for each other; as for instance, bismuth and regulus of cobalt, which cannot be made to unite together by fusion, though they cohere with each other so strongly, that they cannot be separated but by the blow of a hammer.

261
Difference betwixt chemical attraction and that of cohesion.

262
Geoffroy's rule for determining the degree of chemical attraction.

To determine the degrees of attraction betwixt different substances, M. Geoffroy laid it down as a general rule, that when two substances are united, and either quits the other to unite with a third, that which thus unites to the third must be said to have a greater affinity to it than to the substance it has quitted. In many cases, however, the seemingly single decomposition is in truth a double one. Thus, when the vitriolic acid expels the air from a fixed alkali, it does not necessarily follow, that the acid is more attracted by the alkali than the fixed air; for here though the latter resigns its place to the acid, yet the acid gives out its fire to the air; whence a decomposition might take place, even though the attractive powers of both the vitriolic and aerial acid to the alkali were equal.

263
Chemical decompositions, tho' seemingly single are often double.

264
Force of the attractive powers to be determined by numbers.

To attain to any certainty in this matter, therefore, it is necessary to determine the quantity and force of each of the attractive powers, and denote it by numbers. The necessity of this has been observed by Mr Morveau and Mr Wenzel, who have both proposed methods for answering the purpose; but Mr Kirwan has showed that both are defective: and he tells us, that the discovery of the quantity of real acid in each of the mineral acid liquors, with the proportion of real acid taken up by a given quantity of each basis at the point of saturation, led him unexpectedly to what seems the true method of investigating the quantity of attraction which each acid bears to the several bases to which it is capable of uniting: "for it was impossible (says he) not to perceive, 1. That the quantity of real acid necessary to saturate a given weight of each basis is inversely as the affinity of each basis to such acid. 2. That the quantity of each basis requisite to saturate a given quantity of each acid is directly as the affinity of such acid to each basis. Thus 100 grains of each of the acids require for their saturation a greater quantity of fixed alkali than of calcareous earths, more of this earth than of volatile alkali, more of this alkali than of magnesia, and more of magnesia than of earth of alum.

265
True method of investigating the quantity of attraction each of the acids has for its different bases.

"If an acid be united to less of any basis than is requisite for its saturation, its affinity to the deficient part of its basis is as the ratio which that deficient part bears to the whole of what the acid can saturate. Thus, if 100 grains of vitriolic acid, which can saturate 110 of calcareous earth, be united only to 55, its affinity to the deficient 55 parts should be estimated one half of its whole affinity; but its affinity to the retained part is as its whole affinity."

266
Method of explaining the decompositions effected by acids alone.

To explain the decompositions in which these acids are concerned, we must consider, first, the powers which resist any decomposition, and tend to keep the bodies in their present state; and, secondly, the powers which tend to effect a decomposition and new union; the former our author calls *quiescent affinities*, the latter *divellent*. A decomposition will therefore always take place when the sum of the divellent affinities is greater than the quiescent; and, on the contrary, no decomposition will happen when the sum of the quiescent affinities is greater than that of the divellent. All we have to do therefore is to compare the sums of each of these powers. The method our author takes to compare the affinities together is by the following table; in which the quantity of alkali, earth, &c. saturated by 100 grains of each of the mineral acids, is stated.

267
Quiescent and divellent affinities.

268
Quantity of acid taken up by various bases.

	Veg. fixed alkali.	Mineral alkali.	Calcar. earth.	Vol. alk.	Magnesia.	Earth of alum.
Vitriolic acid	215	165	110	90	80	75
Nitrous acid	215	165	96	87	75	65
Marine acid	215	158	89	79	71	55

These numbers he considers as adequate expressions of the quanity of each of the affinities. Thus the affinity of the vitriolic acid to fixed vegetable alkali is to the affinity with which it adheres to calcareous earth as 215 to 110; and to that which the nitrous acid bears to calcareous earth as 215 to 96, &c. Hence we sum up the powers of affinity betwixt any number of different substances, and account for their decompositions, as in the following example of the double decomposition, which takes place when a solution of vitriolated tartar and solution of lime or chalk in nitrous acid are mixed together.

269
Expressive of the quantity of attraction they have for each of these bases.

270
Decomposition of vitriolated tartar by solution of calcareous earth explained.

Quiescent Affinities.		*Divellent Affinities.*	
Vitriolic acid to vegetable fixed alkali,	215	Vitriolic acid to calcareous earth,	110
Nitrous acid to calcareous earth,	96	Nitrous acid to vegetable alkali,	215
Sum of quiescent affinities	311	Sum of divellent affinities	325

Hence we see that a double decomposition must ensue. The same will be produced, if instead of vitriolated tartar we make use of Glauber's salt; for the sum of the

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the quiescent affinities is [illegible], of the divellent 275; with vitriolic ammoniac the sum of the quiescent is 186, of the divellent 195, &c. In mixing vitriolated tartar with solution of magnesia in nitrous or marine acids, a double decomposition takes place though invisibly, as the vitriolic Epsom salt is very soluble in water, and therefore cannot be precipitated like selenite. In the former case the sum of the quiescent powers is 290, of the divellent 295; in the second 286 and 295.

271 Coincidence of the above table with experience.

Other decompositions take place in the same manner; and from all the facts which our author had occasion to observe, he concludes, that the quantity of each affinity, as determined in the above table, coincides exactly with experience; and that these decompositions are perfectly consistent with the superior affinity which has been hitherto observed in the vitriolic and nitrous acids with fixed alkalies over the calcareous earths; nor do they infringe in the least the known laws of affinity, as has been intimated by some chemists. One fact only, mentioned in Dr Crell's Journal, seems to be repugnant to what is here advanced; and that is, that if solutions of one part of alum and two of common salt be mixed together, evaporated, and set to crystallize, a Glauber's salt will be formed; though, in this case, the sum of the quiescent affinities is 233, and that of the divellent only 223. Mr Kirwan repeated this experiment without success; and Dr Crell himself owns that it will not succeed but in the most intense cold. If it does succeed at all, he says the decomposition must arise from a large excess of acid in the alum, which acted upon and decomposed the common salt: and this explanation is confirmed by the small proportion of Glauber's salt said to be obtained by this process; for from 30lb. of common salt and 16 of alum, only 15 lb. of Glauber's salt were produced; whereas, if the whole of the alum had been decomposed, there should have been formed, according to Mr Kirwan's computation of the quantity of acid in the different salts, 29¼lb, or, according to Mr Bergman's, 22lb. of Glauber's salt.

272 Mistake of Dr Crell corrected.

273 Formation of triple and quadruple salts.

In some cases, the neutral salts have a power of uniting, without any decomposition, or with only a very small one, to a third substance; thus forming triple salts, and sometimes quadruple; which often causes anomalies that have not yet been sufficiently investigated. Volatile alkalies in particular are possessed of the power of uniting with neutral salts in this manner. Hence they seem to precipitate magnesia from Epsom salt, even when perfectly caustic; but this is owing to their combination with that salt, and forming a triple one, which is insoluble in water.

274 Volatile alkalies particularly form salts of this kind.

It seems extraordinary that, according to Mr Kirwan's table, the three mineral acids should have the same affinity to vegetable fixed alkalies, when it is well known that the vitriolic will expel either of the other two from an alkaline basis. In explication of this, Mr Kirwan observes, that nitre is decomposed by the marine acid; and that Glauber's salt and vitriolic ammoniac are decomposed by that of nitre; and that these salts, as well as cubic nitre and nitrous ammoniac, are decomposed by the marine acid.

275 Vitriolic salts decomposed by the nitrous and marine acids.

Mr Kirwan is of opinion, that these decompositions are the effect of a double affinity, or at least of compound forces. He suspected that they arose from the different capacities of the acids for elementary fire; and to determine this matter, he made the following experiments, in which the decompositions were not discovered by crystallization, but by tests.

276 These decompositions supposed to arise from compound forces.

277 Experiments to determine this by the various degrees of heat excited by mixtures.

1. Having procured a quantity of each of the three mineral acids containing the same proportion of real acid, and reduced them to the temperature of 68° of Fahrenheit, 100 grains of vitriolic acid, containing 26.6 of real acid, was projected upon 480 grains of oil of tartar at the same temperature, by which the thermometer was raised to 138°.

2. An hundred grains of spirit of nitre, containing also 26.6, projected on 480 grains of oil of tartar, produced only 120° of heat.

3. An hundred grains of spirit of salt, the specific gravity of which was 1220, and which contained the usual proportion of real acid, raised the thermometer from 69 to 129.

278 Vitriolic acid contains more fire than the nitrous and marine.

"Hence (says he) it follows, that the vitriolic acid contains more specific fire, or at least gives out more by uniting with fixed alkalies, than either the nitrous or marine; and therefore when the vitriolic acid comes in contact with either nitre or salt of Sylvius, its fire passes into these acids, which are thereby rarefied to a great degree, and are thus expelled from their alkaline basis, which is then seized on by the vitriolic."— On this, however, it is obvious to remark, that, according to Mr Kirwan's explanation, the marine acid, as giving out more specific heat, ought to expel the nitrous from an alkaline basis; which, however, is not the case. Something else, therefore, besides the mere quantity of specific heat, must here be taken into consideration. Mr Kirwan, however, goes on to prove the truth of his theory by the following experiments.

279 Difficulty in the theory.

280 On the expulsion of the nitrous acid by the vitriolic diluted.

4. To 400 grains of vitriolic acid, whose specific gravity was 1.362, sixty grains of nitre were added; on which the thermometer fell from 68° to 60°. During the time of this descent, the nitrous acid was not expelled; for some filings of copper, put into the mixture, were not acted upon in the least; but in five minutes afterwards they visibly effervesced, which showed that the nitrous acid began to be expelled; for the vitriolic acid does not act upon copper but by a boiling heat.

281 By the same acid concentrated.

5. Sixty grains of nitre were put to 400 of oil of vitriol, whose specific gravity was 1.870; the thermometer instantly rose from 68° to 105°, and the nitrous acid was expelled in a visible fume.—" These experiments (says Mr Kirwan) prove, 1. That neutral salts are not decomposed by mere solution in an acid different from their own. 2. That the nitrous acid, being converted into vapour, had imbibed a large quantity of fire. But as the vitriolic acid, in both these experiments, was used in much larger quantity than was necessary to saturate the alkali of the nitre, sixty grains of the latter were put into 64 of the abovementioned dilute spirit of vitriol, which contained the same quantity of real vitriolic acid that the 60 grains of nitre did of the nitrous; with the addition of 40 grains of water and a few copper-filings. In less than two hours the copper was acted upon, and consequently the nitrous acid was expelled.

282 With a small quantity of diluted vitriolic acid.

283 On the expulsion of marine acid by the concentrated vitriolic.

6. To 400 grains of oil of vitriol, of the specific gravity of 1.870, 100 grains of common salt were added. An effervescence immediately ensued, and

and the marine acid roſe in white vapours. A thermometer held in the liquor roſe only 4 degrees, but in the froth it aſcended to 10°, and fell again upon being replaced in the liquor. Hence Mr Kirwan concludes, that the vitriolic acid gives out its fire to the marine; and that this latter received more than it could abſorb even in the ſtate of vapour, and therefore communicated heat to the contiguous liquor. It appears to him alſo, that the nitrous and marine acids receive fire from the vitriolic, and are thrown into a vaporous ſtate, or at leaſt rarefied to ſuch a degree as to be expelled from their alkaline baſis, though their affinity with that baſis may be equally ſtrong with the vitriolic.

284
Both the nitrous and marine acids receive fire from the vitriolic during their expulſion.

285
On the decompoſition of vitriolated tartar by nitrous acid.

7. To aſcertain the manner in which vitriolated tartar and Glauber's ſalt are decompoſed by ſpirit of nitre, 60 grains of powdered tartar of vitriol were put into 400 of nitrous acid, whoſe ſpecific gravity was 1.355, and which contained about 105 grains of real acid. The thermometer was not affected by the mixture; but in 24 hours the vitriolic acid was in part diſengaged, as appeared by the acid mixture acting upon regulus of antimony, which neither pure vitriolic nor pure nitrous acid will do by themſelves. On putting the ſame quantity of vitriolated tartar into 400 grains of ſpirit of nitre whoſe ſpecific gravity was 1.478°, the thermometer roſe from 67° to 79°: the vitriolated tartar was quickly diſſolved, and the regulus of antimony ſhowed that the vitriolic acid, was diſengaged. Hence it appeared that the nitrous acid, having the ſame affinity with the baſis of vitriolated tartar as the vitriolic, but giving out, during the ſolution, more fire than was neceſſary to perform the ſolution, the vitriolic, receiving this fire, was diſengaged: for as it cannot unite to alkalies without giving out fire; ſo when it receives back that fire, it muſt quit them. The reaſon why the nitrous acid, which ſpecifically contains leſs fire than the vitriolic, gives out ſo much is, that its quantity in both theſe experiments is far greater than that of the vitriolic; it being in the firſt as 105 to 17, and in the laſt as 158 to 17.

286
Acids unite to alkalies by giving out fire, and quit them by receiving it.

287
Vitriolated tartar cannot be decompoſed by diluted nitrous acid.

8. To 60 grains of ſpirit of nitre, whoſe ſpecific gravity was 1.355, Mr Kirwan added 1000 grains of water; and into this dilute acid put 60 grains of vitriolated tartar, containing exactly the ſame quantity of real acid that the 60 grains of nitrous acid did. In eight days the vitriolated tartar was almoſt entirely diſſolved, and without any ſign of its decompoſition; and no nitre was found upon evaporating the liquor. Hence he concludes, that the nitrous acid can never decompoſe vitriolated tartar, without the aſſiſtance of heat, but when its quantity is ſo great that it contains conſiderably more fire, and by the act of ſolution is determined to give out this fire. This ſalt is alſo decompoſed, in ſimilar circumſtances, by the marine acid; though ſtill more ſlowly and with more difficulty than by the nitrous, as appears by the following experiments.

288
Decompoſition of vitriolated tartar by marine acid.

9. Into 400 grains of ſpirit of ſalt, whoſe ſpecific gravity was 1.220, were put 60 grains of vitriolated tartar. The thermometer was not affected in the leaſt, and the ſalt diſſolved very ſlowly. Some pulverized biſmuth was added to try whether the vitriolic acid was diſengaged; and in 12 hours part of it was diſſolved, ſo that it could not be precipitated by water. This ſhowed, that part of the vitriolic acid was diſlodged; for this ſemi-metal cannot be kept in ſolution when much diluted with water, excepting by a mixture of marine and vitriolic acids.

289
Requiſites for the ſucceſs of this experiment.

In this experiment the quantity of marine acid was much greater than that of the vitriolic; and therefore it was capable of diſlodging it. This circumſtance alone, however, is not ſufficient; the acid muſt be diſpoſed to give out by ſolution that quantity of fire which it is neceſſary the vitriolic ſhould receive in order to its quitting the baſis to which it is united; and therefore when Mr Cornette added two ounces of ſpirit of ſalt to half an ounce of vitriolated tartar already diſſolved, in water, no decompoſition took place. The reaſon of this was, that as the vitriolated tartar was already diſſolved, no cold nor heat was generated by the mixture; and therefore the ſpirit of ſalt could not give out any fire. Glauber's ſalt is more eaſily decompoſed by marine acid then vitriolated tartar, on account of its being more eaſily ſoluble in ſpirit of ſalt; and likewiſe becauſe its alkaline baſis takes up an equal quantity of both acids: conſequently the marine gives out more fire in uniting to the baſis of Glauber's ſalt than on being united to that of vitriolated tartar. Vitriolic ammoniac is alſo decompoſed by means of marine acid; but in all theſe caſes, the quantity of marine acid muſt greatly exceed that of the vitriolic contained in the ſalt to be decompoſed; and it muſt be remarked, that according to the obſervations of Mr Bergman, the decompoſition of Glauber's ſalt or vitriolic ammoniac by this acid is never complete.

290
Vitriolated tartar diſſolved in water cannot be decompoſed by marine acid, and why.

291
Decompoſition of vitriolic ammoniac and Glauber's ſalt by marine acid never complete.

On the ſame principles the marine acid decompoſes ſalts which have the nitrous acid for their baſis. Mr Cornette found, that cubic nitre was more eaſily decompoſed by it than that which has vegetable alkali for its baſis. Accordingly, during the ſolution of priſmatic nitre, only three degrees of cold were produced; but ſix by the ſolution of cubic nitre; which ſhows that the ſpirit of ſalt gave out more fire in the latter caſe than in the former; and its quantity muſt always be greater than that of the nitrous acid contained in the mineral alkaline baſis; becauſe this baſis requires for its ſaturation more of the marine than of the nitrous acid. The nitrous acid, however, in its turn decompoſes ſalt of Sylvius and common ſalt; but it muſt always be in greater quantity than the marine to produce that effect.

292
Nitrous ſalts decompoſed by marine acid.

293
Marine ſalts decompoſed by the nitrous acid.

10. Sixty grains of common ſalt being added to 400 of colourleſs ſpirit of nitre, whoſe ſpecific gravity was 1.478, the mixture quickly effervesced and grew red, yet the thermometer roſe but two degrees; which ſhowed that the marine acid had abſorbed the greater part of the firſt given out by that of nitre; the decompoſition was likewiſe haſtened by the ſuperior affinity of the nitrous acid to the alkaline baſis of the ſea-ſalt: hence the decompoſition of ſea-ſalt by means of nitre takes place without any ſolution; but ſpirit of ſalt will not decompoſe cubic nitre until it has firſt diſſolved it. This mutual expulſion of the nitrous and marine acids by each other, is the reaſon why aqua-regia may be made by adding nitre or nitrous ammoniac to ſpirit of ſalt, as well as by adding common ſalt or ſal ammoniac to ſpirit of nitre.

Selenite cannot be decompoſed either by nitrous or

marine

marine acid; becaufe it cannot be diffolved in either without the affiftance of foreign heat. It muft likewife be obferved, that in all decompofitions of this kind, when the liquor has been evaporated to a certain degree, the vitriolic acid expels in its turn the nitrous or marine acid to which it had already yielded its bafis. The reafon of this is, that the free part of the weaker acids being evaporated, the neutral falts begin to cryftallize, and then giving out heat, the vitriolic abforbs it; and thus reacting upon them expels them from the alkali or earth to which they are united.

294 Selenites cannot be decompofed by marine acid.

295 Why the vitriolic acid affumes on evaporation the bafes it had loft.

296 Difficulties in determining the attractive powers of the acids to metals.

Mr Kirwan found much more difficulty in determining the attractive powers of the different acids to the metals than to alkaline falts or earths. Some of the difficulties met with in this cafe arofe from the nature of metallic fubftances themfelves. Their calces when formed by fire always contain a quantity of air, which cannot be extracted from them without great difficulty, and is very foon re-abforbed; and if formed by folution, they as conftantly retain a part of their folvent or precipitant; fo that the precife weight of the metalline part can fcarce be difcovered. Our author, therefore, and becaufe metallic calces are generally infoluble in acids, chofe to have the metals in their perfect ftate: and even here they muft lofe a part of their phlogifton before they can be diffolved in acids, and a confiderable part remains in the folution of the acid and calx; which laft quantity he endeavoured to determine.

297 Metallic falts infoluble in water without an excefs of acids.

A new difficulty now occurred, arifing from the impoffibility of finding the real quantity of acid neceffary to faturate the metal, for all metallic folutions contain an excefs of acid: the reafon of which is, that the falts formed by a due proportion of acid and calx are infoluble in water without a further quantity of acid; and in fome cafes this quantity, and even its proportion to the aqueous part of the liquor, muft be very confiderable, as in folutions of bifmuth. It was in vain attempted to deprive thofe folutions of their excefs of acid by means of cauftic alkalies and lime-water; for when deprived of only part of it, many of the metals were precipitated, and all of them would be fo if deprived of the whole. As the folution of filver, however, can be very much faturated, Mr Kirwan began with it and found that 657 grains of this folution contained 100 grains of filver, and 31.38 grains of real acid, after making the proper allowance for the quantity diffipated in nitrous air. Nine grains of this folution tinged an equal quantity of folution of litmus as red as $\frac{8}{15}$ of a grain of real acid of fpirit of nitre would have done; whence our author concluded that 9 grains of his folution of filver contained an excefs of $\frac{8}{15}$ of a grain of real filver: according to which calculation, the whole quantity ought to have contained 5.6 grains; which deducted from 31.38, leaves 25.78 grains for the quantity of acid faturated by 100 grains of filver.

As the vitriolic folutions of tin, bifmuth, regulus of antimony, nickel, and regulus of arfenic, contain a large excefs of acid, Mr Kirwan faturated part of it with cauftic volatile alkali before he tried them with the infufion of litmus; and the fame method was ufed with folutions of iron, lead, tin, and regulus of antimony in the nitrous and marine acids. The proportion of vitriolic and marine acid taken up by lead, filver, and mercury, were determined by computing the quantity of real acid neceffary to precipitate thefe metals from their folutions in the nitrous acid; which feemed to be the moft exact method of determining this point. The refult of all the experiments was, that 100 grains of each of thefe acids take up at the point of faturation of each metallic fubftance, dephlogifticated fuch a degree as is neceffary for its folution in each acid, the quantities marked in the following table.

298 Quantities of the different metals taken up by acid.

100 grains of	Iron.	Copper.	Tin.	Lead.	Silver.	Merc.	Zinc.	Bifmuth.	Nickel.	Cobalt.	Reg. of ant.	Reg. of arfen.
Vitriolic acid	270	260	138	412	390	432	318	250 310	320	360	200	260
Nitrous acid	255	255	120	365	375	416	304	290	300	350	194	220
Marine acid	265	265	130	400	420	438	312	250 320	275 310	370	198	290

Though from this table, compared with the former, we might fuppofe that metals, having a greater attraction for acids than alkalies, could not be precipitated by them, yet Mr Kirwan obferves, that the common tables, which poftpone metallic fubftances to alkaline falts, are in reality juft, though there can fcarce be any room to doubt that almoft all metallic fubftances have a greater affinity with acids than alkalies have. The common tables, he fays, are tables of precipitation rather than of affinity, as far as they relate to metallic fubftances. Thefe precipitations, however, are conftantly the refult of a double affinity and decompofition; the precipitating metal yielding its phlogifton to the precipitated one, while the precipitated metal yields its acid to the other. Thus, though copper in its metallic form precipitates filver and mercury from the nitrous acid, yet the calx will precipitate neither.

299 Metals have a greater affinity with acids than alkalies.

300 Why alkalies precipitate the metals.

301 Nitrous acid attracts filver more than fixed alkali.

The fuperior attraction the nitrous acid has to filver rather than fixed alkali, appears from the following experiment. If a folution of filver in nitrous acid be poured into a mixed folution of alkali and fea-falt, the filver will be precipitated by the fea-falt into a luna cornea, and not by the loofe alkali contained in the liquor. "Now (fays Mr Kirwan), if the nitrous acid had a greater affinity to the free alkali than to the filver, it is evident that the filver would be precipitated pure, and not in the ftate of luna cornea; but from its being precipitated in this ftate, it is plain, that the precipitation was not accomplifhed by a fingle but by a double affinity. Hence alfo the marine acid appears to have a greater attraction to filver than the nitrous has to fixed alkalies. The refult is fimilar when we make ufe of folutions of lead or mercury in the nitrous acid. Mr Bayen has alfo fhown, that vitriol of lead and corrofive fublimate mercury cannot be deprived of more than half their acid, even by cauftic fixed alkalies.

With

302 Sea-ſalt decompoſed in various ways by means of lead.

With regard to lead, if perfectly dry ſalt be projected on this metal heated to ignition, the common ſalt will be decompoſed, and plumbum corneum formed. Nor can we attribute this to the volatilization of the alkali by heat; for the alkali is as fixed as the lead, and muſt therefore be cauſed by the ſuperior attraction which the calx of this metal, even when dephlogiſticated, has for the marine acid. Mr Scheele informs us, that if a ſolution of common ſalt be digeſted with litharge, the common ſalt will be decompoſed, and a cauſtic alkali produced. It may alſo be decompoſed ſimply by letting its ſolution paſs ſlowly through a funnel filled with litharge; and the ſame thing happens to a ſolution of calcareous earth in marine acid; which ſhows that the decompoſition takes place merely by the ſuperior degree of attraction betwixt the acid and metallic calx (A).

303 Acids attract metallic earth more ſtrongly than volatile alkali.

That acids have a greater attraction for metallic earths than volatile alkalies, is ſtill more evident. Luna cornea is ſoluble in volatile alkalies; but if this ſolution be triturated with four times its weight of quickſilver, a *mercurius dulcis*, and not ſal ammoniac, is formed. The reaſon why alkalies and earths precipitate all metallic ſolutions is, that the metals are held in ſolution by an exceſs of acid. Even if the alkaline and earthy ſubſtance did no more than abſorb this exceſs of acid, a precipitation muſt neceſſarily enſue; but they not only take up this ſuperabundant acid, but alſo the greater part of that which is neceſſary to ſaturate the metallic earth. This they are enabled to do by means of a double affinity; for during the ſolution of metals, only a ſmall part of the phlogiſton, comparatively ſpeaking, eſcapes, the remainder being retained by the compound of acid and calx. When therefore an alkali or earth is added to ſuch a ſolution, the phlogiſton quits the acid, and joins with the calx, while the greater part of the acid reunites to the precipitate.

304 Why the metallic earths ſeldom decompoſe ſalts having an earth or alkali for their baſis.

Notwithſtanding this great affinity, however, of metallic earths to acids, there are but few inſtances of their decompoſing thoſe ſalts which have an alkali, or an earth for their baſis, by reaſon of the inability of the acids, while combined with theſe baſes, and thereby deprived of a great part of their ſpecific fire, to volatilize the phlogiſton combined with the metallic earths, which muſt neceſſarily be expelled before an acid can combine with them: and as to the metallic calces, they are generally combined with fixed air, which muſt alſo be partly expelled; but ammoniacal ſalts (containing much more fire, for they abſorb it during their formation) for that reaſon act much more powerfully on metals. Allowing then the affinities of the mineral acids with metallic ſubſtances to be as above, all double decompoſitions, in which only ſalts containing theſe acids united to alkaline, terrene, or metallic baſes, are concerned, admit of an eaſy explanation; nay, ſays Mr Kirwan, I am bold to ſay, they cannot otherwiſe be explained.

305 Decompoſition of vitriolated tartar by ſolution of ſilver explained;

Thus, if a ſolution of tartar vitriolate, and of ſilver in the nitrous acid, be mixed in proper proportion, nitre and vitriol of ſilver will be formed; and this latter for the moſt part precipitated.

Quieſcent Affinities		*Divellent Affinities.*	
Nitrous acid to ſilver,	375	Nitrous acid to vegetable alkali,	215
Vitriolic acid to vegetable alkali,	215	Vitriolic acid to ſilver,	390
	590		605

306 And of Glauber's ſalt, vitriolic ammoniac, &c.

Thus alſo, if, inſtead of a ſolution of tartar vitriolate, that of Glauber's ſalt, or of vitriolic ſal ammoniac, ſelenite, Epſom ſalt, or alum, be uſed, the balance is conſtantly in favour of the divellent powers; and a precipitation is the conſequence, though but ſlight when ſelenite or alum are uſed.

307 In what caſes ſolution of ſilver is precipitated by other metals.

Solution of ſilver is alſo precipitated by the vitriolic ſolutions of iron, copper, tin, and probably by many other ſolutions of metals in the vitriolic acid: for this reaſon, among others undoubtedly, that they contain an exceſs of acid: but if a ſaturated ſolution of ſilver be mixed with a very ſaturated ſolution of lead or mercury in the vitriolic acid, the ſilver will not be precipitated; and in both caſes the balance is in favour of the quieſcent affinities.

308 Conſtantly decompoſed by marine ſalts;

All the marine neutral ſalts, whether the baſis be alkaline, terrene, or metallic, decompoſe the nitrous ſolution of ſilver; and theſe decompoſitions are conſtantly indicated by the balance of affinities already deſcribed. The ſame thing alſo takes place with ſolution of ſilver in the vitriolic acid, as is indicated alſo by the ſame table.

309 As alſo ſolution of lead.

The nitrous ſolution of lead is alſo decompoſed, and the metal for the moſt part precipitated, unleſs the ſolution be very dilute in the form of vitriol of lead, by all the neutral ſalts containing either the vitriolic or marine acid, excepting only the combination of ſilver with marine acid, which precipitates it in no other way than by its exceſs of acid.

310 Solution of lead in marine acid decompoſed by vitriolic ſalts;

Solution of lead in marine acid is decompoſed by all the neutral ſalts containing the vitriolic acid, excepting only ſelenite and ſolution of nickel in oil of vitriol. Theſe can only precipitate it by virtue of an exceſs of acid.

311 Alſo nitrous ſolutions of mercury;

Nitrous ſolution of mercury is decompoſed by all the neutral ſalts containing the vitriolic acid, except vitriol of lead, which only decompoſes it by an exceſs of acid. All the ſalts containing marine acid decompoſe the nitrous ſolution of mercury, excepting the combinations of marine acid with ſilver and lead, which decompoſe it by exceſs of acid.

312 And by the ſalts containing marine acid.

Theſe ſalts alſo decompoſe vitriol of mercury, tho' a precipitation does not always appear, owing, as Mr Kirwan ſuppoſes, to the facility with which a ſmall quantity of the marine ſalt of mercury is ſoluble in an exceſs of acid.

313 Vitriol of mercury decompoſed by marine acid.

Marine ſalt of ſilver, however, decompoſes vitriol of mercury only through its exceſs of acid. Hence we ſee why luna cornea can never be reduced by fixed alkalies without loſs; and were it not that the action of the alkali is aſſiſted by heat, it never could be reduced by them at all.

314 Why luna cornea cannot be reduced without loſs by alkaline ſalts.

When oil of vitriol is mixed with a ſolution of corroſive ſublimate, a precipitate falls; but this, as Mr Bergman remarks, does not proceed from a decompo- ſition

(A) Theſe experiments have been repeated by many other chemiſts without ſucceſs; and Mr Wiegleb informs, that none of thoſe who have attempted to decompoſe ſea-ſalt by means of lead, ever found their methods anſwer the purpoſe.

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sition of the mercurial salt, but from an abstraction of the water necessary to keep the sublimate dissolved.

315 **Precipitation of corrosive mercury by oil of vitriol explained.**

In the foregoing table two different affinities are assigned to the vitriolic acid with regard to bismuth and nickel; one showing the affinity which these acids bear to the metals when dephlogisticated only by solution in the acids; the other that which the acids bear to them when more dephlogisticated, as when they are dissolved in the nitrous acid. On the other hand, all the acids have less affinity with the calces of iron, zinc, tin, and antimony, when they are dephlogisticated to a certain degree; but our author found himself unable to give any certain criteria of this dephlogistication.

316 **Table of the affinities to the different metals explained.**

317 **Of the quantity of phlogiston contained in the different metals.**

The most difficult point to be settled was the precipitation of metals by each other from the mineral acids. To determine this it was necessary to find the quantity of phlogiston in each of them, not only in their natural state, but according to their various degrees of dephlogistication by each of the acids. The substance he chose for determining the absolute quantity of phlogiston in a metallic substance was regulus of arsenic. An hundred grains of this semimetal dissolved in dilute nitrous acid yielded 102.4 cubic inches of nitrous air; which, according to his calculations on that subject, contain 6.86 grains of phlogiston: and hence he concluded that 100 grains of regulus of arsenic contain 6.86 grains of phlogiston. From this experiment, three times repeated with the same success, our author proceeded to form, by calculation, a table of the absolute quantity of phlogiston contained in metals, the relative quantity having been computed by Mr Bergman and his calculations adopted by our author. These quantities are as follow.

318 **Method of calculating this quantity exemplified in regulus of arsenic.**

319 **Table of the quantities of phlogiston in different metals.**

		Relative Quantity.	Absolute Quantity
100 grains	Gold	394	24.82
	Copper	312	19.65
	Cobalt	270	17.01
	Iron	233	14.67
	Zinc	182	11.46
	Nickel	156	9.82
	Regulus of antimony	120	7.56
	Tin	114	7.18
	Regulus of arsenic	109	6.86
	Silver	100	6.30
	Mercury	74	4.56
	Bismuth	57	3.59
	Lead	43	2.70

320 **Experiments explaining the reduction of silver *per se*.**

This point he likewise endeavoured to ascertain by other experiments. As silver loses a certain quantity of phlogiston, which escapes and separates from it during its solution in nitrous acid, he concluded, that if the solution was exposed to nothing from which it could obtain phlogiston, and this was distilled to dryness, and entirely separated from the acid, as much silver should remain unreduced as corresponded with the quantity of phlogiston lost by it; and if this quantity corresponded with that in the above table, he then had good reason to conclude that the table was just.

For this purpose 120 grains of standard silver were dissolved in dephlogisticated nitrous acid diluted with water, and he obtained from it 24 cubic inches of nitrous air. This solution was gently evaporated to dryness; and he found that, during the evaporation, about a quarter of a grain of the silver had been volatilized. The dry residuum was then distilled, and kept an hour in a coated green-glass retort heated almost to a white heat. Abundance of nitrous acid passed off during the operation, and a green and white sublimate rose into the neck of the retort, some of it even passing over into the receiver. On breaking the retort, the inside was penetrated with a yellow and red tinge, and partly covered over with an exceedingly fine silver powder, which could scarcely be scraped off. The remainder of the silver was white, and perfectly free from acid, but not melted into a button. On being collected, it weighed 94 grains; consequently 26 grains had been lost either by sublimation or vitrification; but of these 26 grains 9 were copper; for 100 grains of standard silver contain $7\frac{1}{2}$ of copper, therefore only 17 grains of pure silver remained unreduced, being either volatilized or vitrified. The whole quantity of pure silver in 120 grains of standard silver amounts to 111 grains; then if 111 grains of pure silver lose 17 by being deprived of its phlogiston, 100 grains of the same should lose 15.3; and by the above table 15.3 grains of silver should contain 0.945 of a grain of phlogiston. Now, 100 grains of pure silver afford 14 cubic inches of nitrous air, which, according to our author's calculation, contain 0.938 of a grain of phlogiston; and this differs from 0.945 only by .007 of a grain. "In this experiment (says Mr Kirwan) only as much of the silver sublimed as could not regain phlogiston; the remainder regained it from the nitrous air absorbed by the solution, and by that which remained in the acid and calx. If this were not so, I do not see why the whole of the silver would not sublime."

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321 **Quantity of pure metal contained in standard silver.**

322 **Examination of Dr Priestley's experiment concerning the revival of mercury.**

Dr Priestley having several times dissolved mercury in the nitrous acid, and revivified it by distilling over that acid, constantly found a considerable portion of it unreduced. To try whether that proportion corresponded with his calculation, Mr Kirwan examined Dr Priestley's experiment, *viz.* that having dissolved 17 penny-weights 13 grains (321 grains) of mercury in nitrous acid, 36 grains remained unreduced. According to Mr Kirwan's calculation 56 grains should have remained unreduced; for 100 grains of mercury afford 12 cubic inches of nitrous air; of consequence 321 grains should afford 38.52, which contain 2.58 of phlogiston: and if, as according to the table, 4.56 grains of phlogistion be necessary to metallize 100 grains of mercury, 2.58 grains will be necessary to metallize 56 grains of the same metal; and our author is satisfied from his own trials, that more than 50 grains would have remained unreduced, if dephlogisticated nitrous acid had been used in dissolving the mercury, and the solution performed with heat and a strong acid: but that which the Doctor used was of the smoking kind, and consequently contained a considerable quantity of phlogiston already, which undoubtedly contributed to revive more of the metal than would otherwise have been done. It is true, Dr Priestley afterwards revived a great part of what had originally remained unreduced, but this happened after it had been some time exposed to the free air, from which the calces of metals always attract phlogiston; as is evident in luna cornea, which blackens on being exposed to the air.

323 **Why so much of the metal was revived in the Doctor's experiments.**

By another experiment of Dr Priestley's, it was found

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found, that nearly five pennyweights of minium, from whence all its air was extracted, that is, about 118 grains, absorbed 40 ounce-measures, or 75.8 cubic inches of inflammable air, containing 2.65 grains of phlogiston, by which they were reduced.

324 Of the revival of lead from minium by inflammable air.

An hundred grains of minium, therefore, require for their reduction nearly 2.25 grains of phlogiston. In another experiment made with more care, he found, that 480 grains of minium absorbed 108 ounce-measures of inflammable air; so that, according to this, 100 grains of minium require for their reduction 1.49 grains of phlogiston; and in two succeeding experiments he found the quantity still less.

325 Mr Kirwan's remarks on the experiments of Dr Priestley.

On this Mr Kirwan remarks, 1. That the whole of the minium was not dephlogisticated; for it is never equally calcined, and besides much of it must have been reduced during the expulsion of its air. 2. The quantity of phlogiston in the inflammable air may have been greater, as this varies with its temperature and the weight of the atmosphere: so that on the whole these experiments confirm the results expressed in the table.

326 Of the attraction of metallic calces to phlogiston.

Mr Kirwan next proceeds to consider the attraction of metallic calces to phlogiston. Inflammable air, when condensed into a solid substance, he supposes not only equal, but much superior, to any metallic calx in specific gravity; and therefore, if we could find the specific gravity of any calx free both from phlogiston and fixed air, we would thus know the density which phlogiston acquires by its union with such calx.

327 Of finding the specific gravity of the different metallic calces.

It has, however, hitherto proved impossible to procure calces in such a state; as, during their dephlogistication, they combine with fixed air or some particles of the menstruum, whence their absolute weight is increased, and their specific gravity diminished. Hence it appears, that the specific gravity of the calces differs much less from that of their respective metals, than the specific gravity which the phlogiston acquires by its union with those calces from that which it possesses in its uncombined state. Hence, instead of deducing the quantity of affinity betwixt phlogiston and metallic calces from the following proposition, that "the affinity of metallic calces to phlogiston is in a compound ratio of its quantity and density in each metal," he is obliged

328 Whence their various degrees of affinity to phlogiston may be determined.

to deduce it from this other, that "the affinity of metallic calces to phlogiston is directly as the specific gravity of the respective metals, and inversely as the quantity of calx contained in a given weight of these metals." This latter proposition is an approximation to the former, founded on this truth, that "the larger the quantity of phlogiston in any metal is, the smaller is the quantity of calx in a given weight of that metal;" and, that "the density which the phlogiston acquires is as the specific gravity of the metal." This latter proposition, however, is not strictly true, for this density is much greater; but its defect is only sensible with regard to those metals which contain a considerable quantity of phlogiston, as gold, copper, cobalt, and iron. With regard to the rest, it is of no importance. The specific gravity of the different metals, then, being as represented in the first column of the following table, the affinity of their calces to phlogiston will be as in the second; and the third expresses the affinities in numbers homogeneous with those which express the affinities of acids with their basis.

330 Table of the proportional affinities of metallic calces to phlogiston.

	Specific Gravity.	Proportionable Affinities.	Real Affinities of Calx to Phlogist.
Gold	19	0.25	1041
Mercury	14	0.147	612
Silver	11.091	0.118	491
Lead	11.33	0.116	483
Copper	8.8	0.109	454
Bismuth	9.6	0.099	412
Cobalt	7.7	0.092	383
Iron	7.7	0.090	375
Regulus of Arsenic	8.31	0.089	370
Zinc	7.24	0.0812	338
Tin	7	0.075	312
Regulus of Antimony	6.86	0.074	308

331 Why lead is useful in cupellation.

From this table we may see why lead is useful in cupellation; namely, because it has a greater affinity with phlogiston than the calces of any of the other imperfect metals; consequently after it has lost its own phlogiston, it attracts that of the other metals with which it is mixed, and thus promotes their calcination and vitrification.

332 Quantity of phlogiston lost by metals during calcination.

The third point necessary for the explanation of the phenomena attending the solution of metals, and their precipitation by each other, is to determine the proportion of phlogiston which they lose by solution in each of the acids, and the affinity which their calces bear to the part so lost. Though our author was not able to determine this by any direct experiment, yet from various considerations he was led to believe that it was as follows:

Quantity of Phlogiston separated

From	Iron,	Copper,	Tin,	Lead,	Silver,	Mercury,	Zinc,	Bismuth,	Cobalt,	Nickel,	Reg. of Ant.	Reg. of Ars.
By the vitriolic acid	$\frac{2}{3}$	$\frac{8}{10}$	$\frac{7}{10}$	$\frac{93}{100}$	Entire	$\frac{87}{100}$	$\frac{85}{100}$	$\frac{85}{100}$	$\frac{93}{100}$	Entire	$\frac{97}{100}$	$\frac{86}{100}$
By nitrous acid	$\frac{2}{3}$	$\frac{81}{100}$	$\frac{7}{10}$	$\frac{88}{100}$	Entire	$\frac{9}{10}$	$\frac{99}{100}$	$\frac{97}{100}$	Entire	Entire	Entire	$\frac{99}{100}$
By marine acid	$\frac{42}{100}$	$\frac{57}{100}$	$\frac{3}{10}$	$\frac{6}{10}$	——	——	$\frac{6}{10}$	$\frac{7}{10}$	$\frac{94}{100}$	$\frac{8}{10}$	$\frac{84}{100}$	$\frac{8}{10}$

329 Of the affinity of calces to the deficient part of their phlogiston.

The affinity of the calces to the deficient part of their phlogiston may now be easily calculated; for they may be considered as acids, whose affinity to the deficient part of their basis is as the ratio which that part bears to the whole. Thus the affinity of iron, thoroughly deprived of its phlogiston, being 375, as it loses two-thirds of its phlogiston by solution in the vitriolic acid, the affinity of iron to these is two-thirds of its whole affinity; that is, two-thirds of 375, or 250.

333 Use of these calculations and tables for knowing *à priori* the phenomena of precipitation.

Thus we may easily construct a table of the affinities of the phlogiston of different metals for their calces; and from this and that formerly given, by which the affinities of the acids to the metallic calces was expressed, we may guess what will happen on putting one metal in the solution of another. Thus if a piece of copper be put into a saturated solution of silver, the silver will be precipitated; for the balance is in favour of the divellent powers, as appears from the following calculation.

Quiescent

Solution and Precipitation.

Quieſcent Affinities.		*Divellent Affinities.*	
Nitrous acid to ſilver	375	Nitrous acid to copper	255
Calx of copper to phlogiſton	363	Calx of ſilver to phlogiſton	491
Sum of the quieſcent affinities	738	Sum of the divellent	746

334 Of the exceſs of acid in ſolutions proper for making theſe experiments.

In making theſe experiments the ſolutions muſt be nearly, though not entirely, ſaturated. If much ſuperfluous acid be left, a large quantity of the added metal will be diſſolved, before any precipitation can be made to appear; and when the ſolution is perfectly ſaturated, the attraction of the calces for one another begins to appear; a power which ſometimes takes place, and which has not yet been fully inveſtigated.

335 Why the metals are more dephlogiſticated by mutual precipitation than by direct ſolution.

In this way the precipitating metals are more dephlogiſticated than by direct ſolution in their reſpective menſtrua; and are even diſſolved by menſtrua which would not otherwiſe affect them. The reaſon of this is, that their phlogiſton is acted upon by two powers inſtead of one: and hence, though copper be directly ſoluble in the vitriolic acid only when in its concentrated ſtate, and heated to a great degree; yet if a piece of copper be put into a ſolution of ſilver, mercury, or even iron, though dilute and cold, and expoſed to the air, it will be diſſolved; a circumſtance which has juſtly excited the admiration of ſeveral eminent chemiſts, and which is inexplicable on any other principles than thoſe juſt now laid down. From this circumſtance we may ſee the reaſon why vitriol of copper, when formed by nature, always contains iron.

336 Why copper is diſſolved by ſolution of ſilver, mercury, or iron.

Mr Kirwan now proceeds to conſider the ſolutions of metallic ſubſtances in all the different acids.

337 Iron and zinc the only metals diſſolved by vitriolic acid.

Vitriolic acid, he obſerves, diſſolves only iron and zinc of all the metallic ſubſtances, becauſe its affinity to their calces is greater than that which they bear to the phlogiſton they muſt loſe before they can unite with it.

338 Nitrous acid diſſolves all metals, though it has leſs affinity with them than the vitriolic or marine.

Nitrous acid has leſs affinity with all metallic ſubſtances than either the vitriolic or marine; yet it diſſolves them all, gold, ſilver, and platina excepted, though it has even leſs affinity with them than they have with that portion of phlogiſton which muſt be loſt before they can diſſolve in any acid. The reaſon of this is, that it unites with phlogiſton, unleſs when in too diluted a ſtate; and the heat produced by its union with phlogiſton is ſufficient to promote the ſolution of the metal. On the other hand, when very concentrated, it cannot diſſolve them: becauſe the acid does not then contain fire enough to throw the phlogiſton into an aerial form, and reduce the ſolid to a liquid.

339 Why it cannot diſſolve them when much concentrated.

340 In what caſes the marine acid can diſſolve metals, and when it cannot.

The marine acid dephlogiſticates metals leſs powerfully than any other. It can make no ſolution, or at leaſt can operate but very ſlowly, without heat, in thoſe caſes where the metallic calx has a ſtronger affinity with that portion of the phlogiſton which muſt be loſt, than the acid: nor can it operate briſkly even where the attraction is ſtronger, provided, the quantity of acid be ſmall; becauſe ſuch a little quantity of acid does not contain fire enough to volatilize the phlogiſton: and hence heat is neceſſary to aſſiſt the marine acid in diſſolving lead. When dephlogiſticated, it acts more powerfully.

341 Why copper and iron precipitate one another.

It has been obſerved, that copper and iron mutually precipitate one another. If a piece of copper be put into a ſaturated ſolution of iron freſh made, no precipitation will enſue for 12 hours, or even longer, if the liquor be kept cloſe from the air; but if the liquor be expoſed to the open air, the addition of volatile alkali will ſhow, in 24 hours, that ſome of the copper has been diſſolved, or ſooner, if heat be applied, and a calx of iron is precipitated. The reaſon of this will be underſtood from the following ſtate of the affinities.

Quieſcent.		Divellent.	
Vitriolic acid to calx of iron - -	270	Vitriolic acid to copper - -	260
Copper to its phlogiſton - -	360	Calx of iron to phlogiſton - -	250
	360		510

In this caſe no decompoſition can take place, becauſe the ſum of the divellent affinities is leſs than that of the quieſcent; but in the ſecond, when much of the phlogiſton of the iron has eſcaped, the affinity of the calx of iron to the acid is greatly diminiſhed, at the ſame time that the affinity of the calx to phlogiſton is augmented. The ſtate of the affinities may therefore be ſuppoſed as follows.

Quieſcent.		*Divellent.*	
Vitriolic acid to calx of iron -	240	Vitriolic acid to copper -	260
Copper to its phlogiſton -	360	Calx of iron to phlogiſton -	370
	600		630

342 Increaſe of the attraction of calx of iron to phlogiſton demonſtrated.

The increaſe of affinity of the calx of iron to phlogiſton is not a mere ſuppoſition; for if we put ſome freſh iron to a ſolution of the metal ſo far dephlogiſticated as to refuſe to cryſtallize, ſo much of the phlogiſton will be regained that the impoveriſhed ſolution will now yield cryſtals. The reaſon why the increaſed quantity of phlogiſton does not enable the acid to react upon the metal is, becauſe it is neither ſufficiently large, nor attracted with a ſufficient degree of force, to which the acceſs of air and heat employed contribute conſiderably. The diminution of attraction in calces of iron for acids is evident, not only from this but many other experiments; and particularly from the neceſſity of adding more acid to a turbid ſolution of iron in order to re-eſtabliſh its tranſparency.

343 Calces of copper precipitate dephlogiſticated ſolutions of iron.

A dephlogiſticated ſolution of iron is alſo precipitated by the calces of copper. The ſame thing happens to a ſolution of iron in nitrous acid; only as the acid predominates greatly in this ſolution, ſome of the copper is diſſolved before any of the iron is precipitated. Copper precipitates nothing from ſolution of iron in the marine acid, though expoſed to the open air for 24 hours.

344 Martial vitriol procured by precipitation of copper leſs fit for dyeing than the common.

Solution of copper in the vitriolic acid is inſtantly precipitated by iron; the reaſon of which is plain from the common table of affinities: and hence the foundation of the method of extracting copper, by means of iron, from ſome mineral waters. The precipitated ſolution affords a vitriol of iron, but of a paler kind than that commonly met with, and leſs fit for dyeing, as being more dephlogiſticated: the reaſon of which is, that copper contains more phlogiſton than iron: old iron is alſo uſed which has partly loſt its phlogiſton.

giſton. Hence the iron is more dephlogiſticated by precipitating copper than by mere diſſolution in the vitriolic acid; and hence caſt iron, according to the

345 Solution of copper ſcarcely decompoſed by caſt iron.

obſervations of Mr Schlutter, will ſcarcely precipitate a ſolution of copper; becauſe it contains leſs phlogiſton than bar-iron, as Mr Bergman has informed us.

Mr Kirwan always found ſilver eaſily precipitated by means of iron from its ſolution in nitrous acid; though Bergman had obſerved that a ſaturated ſolution of ſilver could not be thus precipitated without great difficulty, even though the ſolution were diluted and and an exceſs of acid added to it. What precipitation

346 Why a ſaturated ſolution of ſilver can ſcarce be precipitated by iron.

took place could only be accompliſhed by ſome kinds of iron. The reaſon of this Mr Kirwan ſuppoſes to be, that the ſolution, even after it is ſaturated, takes up ſome of the ſilver in its metallic form; which Mr Scheele has alſo obſerved to take place in quickſilver. The laſt portions of both theſe metals when diſſolved in ſtrong nitrous acid, afford no air, and conſequently are not dephlogiſticated. This compound of calx, therefore, and of ſilver in its metallic ſtate, it may reaſonably be ſuppoſed cannot be precipitated by iron, as the ſilver in its metallic form prevents the calx from coming into contact with the iron, and extracting the phlogiſton from it; and for the ſame reaſon iron has been obſerved not to precipitate a ſolution of mercury in the nitrous acid.

347 Of the precipitation of zinc and iron by one another.

Zinc cannot precipitate iron, as Mr Bergman has ſhown, until the ſolution of the latter loſes part of its phlogiſton. Hence we may underſtand why Newmann denied that iron can be precipitated by means of zinc. Mr Kirwan, however, has found, that zinc does not precipitate iron from the nitrous acid; but on the contrary, that iron precipitates zinc. In a ſhort time the acid rediſſolves the zinc and lets fall the iron, owing to the calx of iron being too much dephlogiſticated. Iron, however, will not precipitate zinc either from the vitriolic or marine acids. Moſt of the metallic ſubſtances precipitated by iron from the nitrous acid are in ſome meaſure rediſſolved ſhortly after; becauſe the nitrous acid ſoon dephlogiſticates the iron too much, then lets it fall, reacts on the other metals, and diſſolves them.

348 Why copper ſometimes cannot precipitate ſilver.

Dr Lewis obſerves, that ſilver is ſometimes not precipitated by copper from the nitrous acid; which happens either when the acid is ſuperſaturated with ſilver by taking up ſome in its metallic form, or when the ſilver is not much dephlogiſticated. In this caſe, the remedy is to heat the ſolution and add a little more acid, which dephlogiſticates it further; but the nitrous acid always retains a little ſilver.

349 Blue vitriol cannot be formed by boiling a ſolution of alum with copper filings.

It has commonly been related by chemical authors, that blue vitriol will be formed by adding filings of copper to a boiling ſolution of alum. Mr Kirwan, however, has ſhowed this to be an error; for after boiling a ſolution of alum for 20 hours with copper filings, not a particle of the metal was diſſolved; the liquor ſtanding even the teſt of the volatile alkali. The alum indeed was precipitated from the liquor, but ſtill retained its ſaline form; ſo that the precipitation was occaſioned only by the diſſipation of the ſuperfluous acid.

350 Why tin cannot be precipitated in its metallic form.

No metal is capable of precipitating tin in its metallic form; the reaſon of which, according to Mr Kirwan, is, becauſe the precipitation is not the effect of a double affinity, but of the ſingle greater affinity of its menſtruum to every other metallic earth. Metals precipitated from the nitrous acid by tin are afterwards rediſſolved, becauſe the acid ſoon quits the tin by reaſon of its becoming too much dephlogiſticated.

351 Why metals precipitated by tin are afterwards rediſſolved.

Lead precipitates metallic ſolutions in the vitriolic and marine acids but ſlowly, becauſe the firſt portions of lead taken up form ſalts very difficult of ſolution, which cover its ſurface, and protect it from the further action of the acid; at the ſame time it contains ſo little phlogiſton, that a great quantity of it muſt be diſſolved before it will diſſolve other metals. A ſolution of lead very much ſaturated cannot be precipitated by iron but with difficulty, if at all. Mr Kirwan conjectures that this may ariſe from ſome of the lead alſo being taken up in its metallic form, as is the caſe with mercury and ſilver. Iron will not precipitate lead from marine acid; for though a precipitate appears the acid is ſtill adhering to the metal. On the contrary, iron is precipitated from its ſolution in this acid by lead, though very ſlowly.

352 Precipitations by lead.

353 Precipitations of mercury by copper.

Mercury is quickly precipitated from the vitriolic acid by copper, though the difference between the ſum of the quieſcent and divellent affinities is but very ſmall. The precipitation, however, takes place, becauſe the calx of mercury has a ſtrong attraction for phlogiſton; and a very ſmall portion of what is contained in copper is ſufficient to revive it.

354 It cannot be precipitated by ſilver from vitriolic acid.

Silver, however, is not able to precipitate mercury from the vitriolic acid, unleſs it contains copper; in which caſe a precipitation will enſue: but on diſtilling ſilver and turpeth mineral, the mercury will paſs over in its metallic form; which ſhows that the affinity of the calx of mercury to phlogiſton is increaſed by heat, though the difference betwixt the divellent and quieſcent powers is very ſmall.

355 Why mercury and ſilver precipitate one another from the nitrous acid.

Mercury appeared to be precipitated by ſilver from the nitrous acid, though very ſlowly; but when the ſolution was made without heat, it was not at all precipitated. On the other hand, mercury precipitates ſilver from this acid, not by virtue of the ſuperiority of the uſual divellent powers, but by reaſon of the attraction of mercury and ſilver for each other; for they form partly an amalgam and partly a vegetation, ſcarcely any thing of either remaining in the ſolution.

356 Corroſive ſublimate cannot be precipitated by ſilver; but luna cornea may be decompoſed by mercury, and ſublimate by ſilver, in the dry way.

Silver does not precipitate mercury from the ſolution of corroſive ſublimate; but, on the contrary, mercury precipitates ſilver from the marine acid: and if a ſolution of *luna cornea* in volatile alkali be triturated with mercury, calomel will be formed; yet on diſtilling calomel and ſilver together, the mercury will paſs in its metallic form, and luna cornea will be formed. The ſame thing happens on diſtilling ſilver and corroſive ſublimate, the affinity of calx of mercury to phlogiſton increaſing with heat.

357 Precipitations of biſmuth.

Biſmuth precipitates nothing from vitriol of copper in 16 hours; nor does copper from vitriol of biſmuth. The two metallic ſubſtances, however, alternately precipitate one another from the nitrous acid, which proceed from their different degrees of dephlogiſtication.

358 Nickel precipitated by zinc.

Nickel will ſcarcely precipitate any metal except it be reduced to powder. A black powder is precipitated by means of zinc from the ſolution of nickel in

in the vitriolic and nitrous acids, which has been ſhown by Bergman to conſiſt of arſenic, nickel, and a little of the zinc itſelf. The latter, however, precipitates nickel from the marine acid.

359 Iron and nickel will ſcarcely precipitate one another.

The ſolutions of iron and nickel in the vitriolic acid mutually act upon theſe metals; but neither of them will precipitate the other in 24 hours, though on remaining longer at reſt iron ſeems to have the advantage. Iron, however, evidently precipitates nickel from the nitrous acid; and though nickel ſeems to precipitate iron, yet this ariſes only from the gradual dephlogiſtication of the iron.

360 Precipitation of copper, lead, and biſmuth by nickel.

Copper is precipitated in its metalic form from the vitriolic, nitrous, and marine acids, by nickel. The vitriolic and nitrous ſolutions of lead ſeem to act upon it without any decompoſition, the calces uniting to each other. Lead ſeems for ſome time to be acted upon in the ſame manner by the vitriolic and nitrous ſolutions of nickel, but at laſt nickel ſeems to have the advantage; but a black precipitate appears which ever of them is put into the ſolution of the other. However, nickel readily precipitates vitriolic and nitrous ſolutions of biſmuth; but in the marine acid both theſe ſemimetals are ſoluble in the ſolutions of each other: yet nickel precipitates biſmuth very ſlowly, and only in part; while biſmuth precipitates a red powder, ſuppoſed by Mr Kirwan to be ochre, from the ſolution of nickel.

361 Zinc cannot precipitate cobalt.

Cobalt is not precipitated by zinc either from the vitriolic or nitrous acids, though it ſeems to have ſome effect upon it when diſſolved in that of ſea-ſalt.

362 Cobalt precipitated by iron.

Iron precipitates cobalt from all the three acids, yet much of the ſemimetal is retained in the vitriolic and nitrous ſolutions of it, particularly the latter; which, after letting fall the cobalt, takes it up again, and lets fall a dephlogiſticated calx of iron.

363 Nickel precipitates ſome heterogeneous matter from it.

Nickel alſo, though it does not precipitate cobalt itſelf, as appears by the remaining redneſs of the ſolution, yet conſtantly precipitates ſome heterogeneous matter from it. Solution of cobalt in the marine acid becomes colourleſs by the addition of nickel.

364 ſolutions of cobalt let fall a white powder on the addition of biſmuth or copper.

Biſmuth is ſoluble in the vitriolic and nitrous ſolutions of cobalt, and throws down a ſmall white precipitate, but does not affect the metallic part. Nor can we attribute theſe ſolutions in vitriolic acid to any exceſs in that acid, as they are dilute and made without heat. Copper alſo precipitates from the ſolution of cobalt a white powder ſuppoſed to be arſenic.

365 Precipitations of and by regulus of antimony.

The regulus of antimony has no effect on ſolution of copper in vitriolic acid, nor is precipitated by it from the ſame acid; but it diſſolves ſlowly in vitriol of antimony. With ſolution of vitriol of lead it becomes red in 16 hours, but is ſcarcely precipitated by lead from the vitriolic acid. Powdered regulus alſo precipitates vitriol of mercury very ſlightly. Biſmuth neither precipitates nor is precipitated by the regulus in 24 hours from the vitriolic acid. Tin precipitates the regulus from the nitrous acid; but if regulus be put into a ſolution of tin in the ſame acid, neither of the metals will be found in the liquid in 16 hours, either by reaſon of the dephlogiſtication or of the union of the calces to each other.

366 A triple ſalt formed by iron, regulus of antimony, and marine acid.

Iron does not precipitate regulus of antimony entirely from the marine acid; but ſeems to form a triple ſalt, conſiſting of the acid and both calces. The regulus may alſo be diſſolved by marine ſalt of iron.

367 Another formed by regulus of antimony, marine acid, and copper.

Copper does not precipitate regulus of antimony from marine acid in 16 hours; and if the regulus be put into marine ſalt of copper, it will be diſſolved, and volatile alkalies will not give a blue, but a yellowiſh white precipitate; ſo that here alſo a triple ſalt is formed.

368 Precipitations of and by arſenic.

Solution of arſenic in vitriolic acid acts upon iron, lead, copper, nickel, and zinc; but ſcarce give any precipitate: neither is arſenic precipitated by iron from the nitrous acid, though it is by copper, and even ſilver gives a ſlight white precipitate. Regulus of arſenic, however, precipitates ſilver completely in 16 hours: whence the former precipitate ſeems to be a triple ſalt. Mercury alſo ſlightly precipitates arſenic from the nitrous acid, and ſeems to unite with it, though it is itſelf precipitated by regulus of arſenic in 24 hours.

369 Regulus of arſenic precipitated by biſmuth from the nitrous acid;

Biſmuth ſlightly precipitates arſenic from ſpirit of nitre, but regulus of arſenic forms a copious precipitate in the nitrous ſolution of biſmuth; ſo that Mr Kirwan is of opinion that the calces unite. It is not precipitated from this acid by nickel, but the calces unite. Though regulus of arſenic produces a copious precipitate in the ſolution of nickel in nitrous acid, yet the liquor remains green; ſo that the nickel is certainly not precipitated. The white precipitate in this caſe ſeems to be arſenic ſlightly dephlogiſticated. Regulus of arſenic alſo produces a white precipitate in the nitrous ſolution of cobalt, but the liquor ſtill continues red.

370 And by copper from the marine acid.

Regulus of arſenic is precipitated from the marine acid by copper; but the precipitate does not ſtrike a blue colour with volatile alkali, becauſe the metal unites with the arſenic. The arſenic is alſo precipitated by iron. Tin is ſoluble in marine ſolution of arſenic, but Mr Kirwan could not obſerve any precipitation; nor does regulus of arſenic precipitate tin. Neither biſmuth nor regulus of arſenic precipitate each other from marine acid in 16 hours. Regulus of antimony is alſo acted upon by the marine ſolution of arſenic, though it cauſes no precipitate, nor does the regulus of arſenic precipitate it.

§ 2. *Of the Quantities of Acid, Alkali, &c. contained in different Salts, with the Specific Gravity of the Ingredients.*

It is a problem by which the attention of the beſt modern chemiſts has been engaged, to determine the quantity of acid exiſting in a dry ſtate in the various compound ſalts, reſulting from the union of acid with alkaline, earthy, and metallic ſubſtances. In this way Mr Kirwan has greatly excelled all others, and determined the matter with an accuracy and preciſion altogether unlooked for. His deciſions are founded on the following principles.

371 Specific gravity of bodies how found.

1. That the ſpecific gravity of bodies is their weight divided by an equal bulk of rain or diſtilled water; the latter being the ſtandard with which every other body is compared.

2. That if bodies ſpecifically heavier than water be weighed in air and in water, they loſe in water part of the weight which they were found to have in air; and

and that the weight so lost is just the same as that of an equal bulk of water; and consequently, that their specific gravity is equal to their weight in air, or absolute weight divided by their loss of weight in water.

3. That if a solid, specifically heavier than a liquid, be weighed first in air and then in that liquid, the weight it loses is equal to the weight of an equal volume of that liquid; and consequently, if such solid be weighed first in air, then in water, and afterwards in any other liquid, the specific gravity will be as the weight lost in it by such solid, divided by the loss of weight of the same solid in water. This method of finding the specific gravity of liquids, our author found more exact than that by the aerometer, or the comparisons of the weights of equal measures of such liquids and water, both of which are subject to several inaccuracies.

372 To find the weight of an equal bulk of water where the specific gravity is known.

4. That where the specific gravity of bodies is already known, we may find the weight of an equal bulk of water; it being as the quotient of their absolute weight divided by their specific gravities: and this he calls their loss of weight in water.

Thus where the specific gravity and absolute weight of the ingredients of any compound are known, the specific gravity of such compound may easily be calculated; as it ought to be intermediate betwixt that of the lighter and that of the heavier, according to their several proportions: and this Mr Kirwan calls the *mathematical* specific gravity.

373 Mathematical specific gravity explained.

But in fact the specific gravity of compounds, found by actual experiment, seldom agrees with that found by calculation; but is often greater, without any diminution of the lighter ingredient.

374 Increased density of mixtures accounted for.

This increase of density, then, Mr Kirwan supposes to arise from a closer union of the component parts to each other than either had separately with its own integrant parts; and this more intimate union must, he thinks, proceed from the attraction of these parts to each other: for which reason he supposed, that this attraction might be estimated by the increase of density or specific gravity, and was proportionable to it; but soon found that he was mistaken in this point.

375 Weights of different kinds of air

With regard to the absolute weights of several sorts of air, our author adheres to the computations of Mr Fontana, at whose experiments he was present; the thermometer being at 55°, and the barometer at 29¼ inches, or nearly so. These weights were as follow:

Cubic inch	of common air, -	0.385
	fixed air, -	0.570
	marine acid air,	0.654
	nitrous air, -	0.399
	vitriolic acid air,	0.778
	alkaline air, -	0.2
	inflammable air,	0.03

376 Method of finding the quantity of pure acid contained in spirit of salt.

Mr Kirwan begins his investigations with the marine acid; endeavouring first to find the exact quantity of pure acid it contains at any given specific gravity, and then by means of it determining the weight of acid contained in all other acids. For if a given quantity of pure fixed alkali were saturated, first by a certain quantity of spirit of salt, and then by determined quantities of the other acids, he concluded, that each of these quantities of acid liquor must contain the same quantity of acid; and this being known, the remainder, being the aqueous part, must also be known. This conclusion, however, rested entirely on the supposition that the same quantity of all the acids was requisite for the saturation of a given quantity of fixed alkali; for if such given quantity of fixed alkali might be saturated by a smaller quantity of one acid than of another, the conclusion fell to the ground. The weight of the neutral salts produced might indeed determine this point in some measure; but still a source of inaccuracy remained; to obviate which he used the following expedient. 1. He supposed the quantities of nitrous and vitriolic acids necessary to saturate a given quantity of fixed alkali exactly the same as that of marine acid, whose quantity he had determined; and to prove the truth of this supposition, he observed the specific gravity of the spirit of nitre and oil of vitriol he employed, and in which he supposed, from the trial with alkalies, a certain proportion of acid and water. He then added to these more acid and water, and calculated what the specific gravity should be on the above supposition; and finding the result agreeable with the supposition, he concluded the latter to be exact. The following experiments were made on the marine acid.

377 Method of finding the specific gravity of spirit of salt.

Two bottles were filled nearly to the top with distilled water, of which they contained in all 1399.9 grains, and successively introduced into two cylinders filled with marine air; and the process was renewed, until the water had imbibed, in 18 days, about 794 cubic inches of the marine air. The thermometer did not rise all this time above 55°; nor sink, unless perhaps at night, above 50°; the barometer standing between 29 and 30 inches. This dilute spirit of salt then weighed 1920 grains; that is, 520.1 more than before; the weight of the quantity of marine air absorbed. The specific gravity of the liquor was found to be 1.225. Its loss of weight in water (that is, the weight of an equal bulk of water) should then be 1567.346 nearly; but it contained only, as we have seen, 1399.9 grains of water: subtracting this therefore from 1567.346, the remainder (that is, 167.446) must be the loss of 520.1 grains of marine acid; and consequently the specific gravity of the pure marine acid, in such a condensed state as when it is united to water, must be $\frac{520.1}{167.446}$, or 3.100.

Still, however, it might be suspected, that the density of this spirit did not entirely proceed from the mere density of the marine acid, but in part also from the attraction of this acid to water; and though the length of time requisite to make the water imbibe this quantity of marine acid air, naturally led to the supposition that the attraction was not very considerable, yet the following experiment was more satisfactory. He exposed 1440 grains of this spirit of salt to marine acid air for five days, the thermometer being at 50°, or below; and then found that it weighed 1562 grains, and consequently had imbibed 122 grains more. Its specific gravity was then 1.253, which was precisely what it should have been by calculation.

378 To find the proportion of pure air in other acid liquors.

Being now satisfied that the proportion of acid in spirit of salt was discovered, our author determined to find it in other acids also. For this purpose he took 180 grains of very strong oil of tartar *per deliquium*, and found that it was saturated by 180 grains of spirit of salt, whose specific gravity was 1.225; and by

calculation

calculation it appeared, that 180 grains of this ſpirit contained 48.7 grains of acid, and 131.3 of water. Hence he drew up a table of the ſpecific gravities of acid liquors containing 48.7 grains of pure acid, with different proportions of water, from 50 to 410 parts; the liquor with the firſt proportion having a ſpecific gravity of 1.497, and the latter weighing only 1.074. Mr Baume had determined the ſpecific gravity of the ſtrongeſt ſpirit of ſalt made in the common manner to 1.187, and Bergman 1.190; but we are told in the Paris Memoirs for 1700, that Mr Homberg had produced a ſpirit whoſe ſpecific gravity was 1.300; and that made by Dr Prieſtley, by ſaturating water with marine acid air, muſt have been about 1.500. The ſpirit of ſalt, therefore, whoſe ſpecific gravity is 1.261, has but little attraction for water, and therefore attracts none from the air; for which reaſon alſo it does not heat the ball of a thermometer, as the vitriolic and nitrous acids do; though Mr Cavallo found that this alſo had ſome effect upon the thermometer. Common ſpirit of ſalt, Mr Kirwan informs us, is always adulterated with vitriolic acid, and therefore unfit for theſe trials.

379 Quantities of acid water, and alkali in digeſtive ſalt

Mr Kirwan now ſet about inveſtigating the quantity of acid, water, and fixed alkali, in digeſtive ſalt, or a combination of the marine acid with vegetable alkali. For this purpoſe he took 100 grains of a ſolution of tolerably pure vegetable alkali, that had been three times calcined to whiteneſs, the ſpecific gravity of which was 1.097; diluting alſo the ſpirit of ſalt with different portions of water; the ſpecific gravity of one ſort being 1.015, and of another 1.098. He then found that the above quantity of ſolution of the vegetable alkali required for its ſaturation 27 grains of that ſpirit of ſalt whoſe ſpecific gravity was 1.098, and 23.35 grains of that whoſe ſpecific gravity was 1.115. Now, 27 grains of ſpirit of ſalt, whoſe ſpecific gravity is 1.098, contain 3.55 grains of marine acid, as appears by calculation. The principles on which calculations of this kind are founded, our author gives in the words of Mr Cotes.

380 How to find the ſpecific gravities of the different ingredients.

"The data requiſite are the ſpecific gravities of the mixture and of the two ingredients. Then, as the difference of the ſpecific gravities of the mixture and the lighter ingredient is to the difference of the ſpecific gravities of the mixture and the heavier ingredient; ſo is the magnitude of the heavier to the magnitude of the lighter ingredient. Then, as the magnitude of the heavier, multiplied into its ſpecific gravity, is to the magnitude of the lighter multiplied into its ſpecific gravity; ſo is the weight of the heavier to the weight of the lighter. Then, as the ſum of theſe weights is to the weight of either ingredient; ſo is the weight given to the weight of the ingredient ſought." Thus, in the preſent caſe, $1.098-1.000=.098$ is the magnitude of the heavier ingredient, viz. the marine acid, and $.098\times3.100=0.3038$ the weight of the marine acid; and on the other hand, $3.100-1.098=2.002$, the magnitude of the water; and $2.002\times1.000=2.002$ its weight; the ſum of theſe weights is 2.3058: then if 2.3058 parts of ſpirit of ſalt contain 0.3038 parts acid, 27 grains of this ſpirit of ſalt will contain 3.55 acid. In the ſame manner it will be found, that 23.35 grains of ſpirit of ſalt, whoſe ſpecific gravity is 1.115, contains 3.55 grains acid.

Our author deſcribes very particularly his method of making the ſaturation of the alkali with the acid; which, as it is always difficult to hit with preciſion, we ſhall here tranſcribe. "It was performed by putting the glaſs cylinder which contained the alkaline ſolution on the ſcale of a very ſenſible balance, and at the ſame time weighing the acid liquor in another pair of ſcales; when the loſs of weight indicated the eſcape of nearly equal quantities of fixed air contained in the ſolution. Then the acid was gradually added by dipping a glaſs rod in it, to the top of which a ſmall drop of acid adhered. With this the ſolution was ſtirred, and very ſmall drops taken up and laid upon bits of paper ſtained blue with radiſh juice. As ſoon as the paper was in the leaſt reddened, the operation was completed; ſo that there was always a very ſmall exceſs of acid, for which half a grain was conſtantly allowed; but no allowance was made for the fixed air, which always remains in the ſolution. But as on this account only a ſmall quantity of the alkaline ſolution was uſed, this proportion of fixed air muſt have been inconſiderable. If one ounce of the ſolution had been employed, this inappretiable portion of fixed air, would be ſufficient to cauſe a ſenſible error; for the quantity of fixed air loſt by the difference betwixt the weight added to the 100 grains and the actual weight of the compound was judged of; and when this difference amounted to 2.2 grains, the whole of the fixed air was judged to be expelled: and it was found to be ſo; as 100 grains of the alkaline ſolution, being evaporated to dryneſs, in the heat of 500°, left a reſiduum which amounted to 10¼ grains, which contained 2.2 grains of fixed air."

381 Mr Kirwan's method of ſaturating the acid and alkali with accuracy.

382 Quantity of mild and cauſtic vegetable alkali ſaturated by a given weight of marine acid.

The reſult of this experiment was, that 8.3 grains of pure vegetable alkali, freed from fixed air and water, or 10.5 of mild fixed alkali, were ſaturated by 3.55 grains of pure marine acid; and conſequently the reſulting neutral ſalt ſhould, if it contained no water, weigh 11.85 grains: but the ſalts reſulting from this union (the ſolution being evaporated to perfect dryneſs in a heat of 160 degrees, kept up for four hours) weighed at a medium 12.66 grains. Of this 11.85 grains were acid and alkali; therefore the remainder, *viz.* 0.81 grains, were water. An hundred grains of perfectly dry digeſtive ſalt contain 28 grains acid, 6.55 of water, and 65.4 of fixed alkali.

383 Nitrous acid, when pure, cannot be made to exiſt in an aerial form.

In his experiments on the nitrous acid, Mr Kirwan made uſe only of the dephlogiſticated kind, which appears pure and colourleſs as water. "This pure acid (ſays he) cannot be made to exiſt in the form of air, as Dr Prieſtley has ſhown; for when it is deprived of water and phlogiſton, and furniſhed with a due proportion of elementary fire, it ceaſes to have the properties of an acid, and becomes dephlogiſticated air. Its proportion therefore could not be determined in ſpirit of nitre as the marine acid had been in ſpirit of ſalt in the laſt experiment."—To determine the matter, the following experiments were made.

384 How to determine the quantity of pure acid contained in ſpirit of nitre.

1. To 1962.25 grains of dephlogiſticated ſpirit of nitre, whoſe ſpecific gravity was 1.419, he gradually added 179.5 grains of diſtilled water; and when it cooled, the ſpecific gravity of the mixture was found to be 1.389.

2. To 1984.5 of this 178.75 grains of water were then added, and the ſpecific gravity of the mixture found to be 1.362.

3. An hundred grains of a ſolution of fixed vegetable

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table alkali, whose specific gravity was 1.097, the same that had been formerly used in the experiments with spirit of salt, was found to be saturated by 11 grains of the spirit of nitre, whose specific gravity was 1.419, by 12 of that whose specific gravity was 1.389, and by 13.08 of that whose specific gravity was 1.362. These quantities were the medium of five experiments; and it was found necessary to dilute the acid with a small quantity of water. When this was neglected, part of the acid was phlogisticated, and flew off with the fixed air. Ten minutes were also allowed after each affusion for the matters to unite; a precaution which was likewise found to be absolutely necessary.

385 Proportion of acid in spirit of nitre to that in spirit of salt.

Upon the supposition, therefore, that a given quantity of vegetable fixed alkali is saturated by the same weight of both acids, we see that 11 grains of spirit of nitre, whose specific gravity is 1.419, contain the same quantity of acid with 27 grains of spirit of salt, whose specific gravity is 1.098, or 3.55 grains. The remainder of 11 grains, or 7.45 grains, is therefore mere water; and of consequence, if the density of the acid and water had not been increased by their union, the specific gravity of the pure nitrous acid should be 11.8729. But the specific gravity of the nitrous, as well as of the vitriolic acid, is augmented by its union with water; and therefore the loss of its weight in water is not exactly, as it would appear by calculation from the above premises, according to the rules already laid down.

386 To find the specific gravity of the pure nitrous acid.

387 How to determine the accrued density on mixing spirit of nitre with water.

To determine therefore the real specific gravity of the acid in its natural state, the quantity of *accrued* density must be found, and subtracted from the specific gravity of the spirit of nitre, whose true mathematical specific gravity will then appear. This our author endeavoured to effect by mixing different portions of spirit of nitre and water, remarking the degree of diminution they sustained by such union; but was never able to attain a sufficient degree of exactness in the experiment. He had recourse therefore to the following method, as affording more satisfaction, though not altogether accurate. Twelve grains of the spirit of nitre, whose specific gravity by observation was 1.389, contained, as our author supposed from the former experiment, 3.55 grains of real acid, and 8.45 of water: then if the specific gravity of the pure nitrous acid were 11.872, that of this compound acid and water should be 1.371; for the loss of 3.55 should be 0.299, and the loss of the water 8.45, the sum of the losses 8.749. Now, $\frac{12}{8.749}=1.371$: but the specific gravity, as already mentioned, was 1.389: therefore the accrued density was at least 0.18. the difference betwixt 1.389 and 1.371. This calculation indeed is not altogether exact: but our author concludes, that 0.18 is certainly a near approximation to the degree of density that accrues to 3.55 grains of acid by their union to 7.45 grains of water: therefore, subtracting this from 1.419, we have nearly the mathematical specific gravity of that proportion of acid and water, namely, 1.401.

388 To determine the mathematical specific gravity of this acid

Again, since 11 grains of this spirit of nitre contain 3.55 grains acid, and 7.45 of water, its loss of weight should be $\frac{11}{1.401}=7.855$; and subtracting the loss of the aqueous part from this, the remainder 0.45 is the loss of the 3.55 grains acid; and consequently the true specific gravity of the pure and mere nitrous acid is $\frac{3.55}{0.405}=8.7654$. This being settled, the mathematical specific gravity and true increase of density of the above mixtures will be found. Thus the mathematical specific gravity of 12 grains of that spirit of nitre, whose specific gravity, by observation, was 1.389, must be 1.355; supposing it to contain 3.55 grains acid and 8.45 of water. For the loss of 3.55 grains acid is $\frac{3.55}{8.763}=0.405$, and the loss of water 8.45; the sum of these losses is 8.855. Then $\frac{12}{8.855}=1.355$; and consequently the accrued density is 1.389—1.355=.034. In the same manner it will be found that the mathematical specific gravity of 13.08 grains of that spirit of nitre, whose specific gravity by observation was 1.362, must be 1.315; and consequently its accrued density .047.

389 Experiment to determine the quantity of real acid in spirit of nitre.

The whole of this, however, still rests on the supposition that each of these portions of spirit of nitre contain 3.55 grains of acid. To verify this supposition, our author examined the mathematical specific gravities of the first mixture he had made of spirit of nitre and water in large quantities; for if the mathematical specific gravities of these agreed exactly with those of the quantities he had supposed in smaller portions of each, he could not but conclude that the suppositions of such proportions of acid and water, as he had determined in each, were just.

390 Table of specific gravities for spirit of nitre, how constructed.

This being determined by proper calculations, Mr Kirwan next proceeded to construct another table of specific gravities, continuing his mixtures, till the mathematical specific gravities found by observation nearly coincided with those made by calculation. In this table the spirit of nitre was mixed with water in various proportions, but after a different manner from that observed with the spirit of salt. Nine grains of the spirit containing 3.55 grains of pure acid were mixed with 5.45 of water; the accrued density of the mixture was found to be nothing, the mathematical specific gravity 1.537, and the specific gravity by observation was found the same. When 10 grains of spirit were mixed with 6.45 of water, the accrued density was 0.009, the mathematical specific gravity 1.458, and the specific gravity by observation 1.467. In this manner he proceeded until 38.90 grains of water were mixed with 42.45 of spirit. In this case the accrued density was found to be 0.002, the mathematical specific gravity 1.080, and the specific gravity by observation 1.082.

The intermediate specific gravities, in a table of this kind, may be found by taking an arithmetical mean betwixt the specific gravities, by observation, betwixt which the desired specific gravity lies, and noting how much it exceeds or falls short of such arithmetical mean; and then taking also an arithmetical mean betwixt the mathematical specific gravities betwixt which that sought for must lie, and a proportionate excess or defect.

The specific gravity of the strongest spirit of nitre yet made, is, according to Mr Baume, 1.500, and according to Mr Bergman 1.586.

Our author next proceeded to examine the propor-

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tion of acid, water, and fixed alkali in nitre, in a manner ſimilar to what he had already done with digeſtive ſalt; and found that 100 grains of perfectly dry nitre contained 23.48 grains of acid, 5.2 of water, and 66.32 of fixed alkali.

391 Quantity of acid, water, and alkali in nitre determined.

Some experiments of the ſame kind had been made by M. Homberg, the reſults of which our author compared with thoſe of his own. The ſpecific gravity of the ſpirit of nitre which M. Homberg made uſe of was 1.349; and of this, he ſays, one ounce two drachms and 36 grains, or 621 troy grains, are required to ſaturate one French ounce (472.5 troy) of dry ſalt of tartar. According to Mr Kirwan's computation, however, 613 grains are ſufficient; for the ſpecific gravity lies between the ſpecific gravities by obſervation 1.362 and 1.337, and is nearly an arithmetical mean between them. The correſponding mathematical ſpecific gravity lies between the quantities marked in Mr Kirwan's table 1.315 and 1.286, being nearly 1.300. Now the proportion of acid and water in this is 2.629 of acid and 7.465 of water; for $8.765 - 1.300 = 7.465$ of water, and $8.765 \times .300 = 2.629$ of acid; and the ſum of both is 10.044. Now, ſince 10.5 grains of mild vegetable alkali require 3.53 grains of acid for their ſaturation, 472.5 will require 159.7; therefore if 10.044 grains of nitre contain 2.629 grains acid, the quantity of this ſpirit of nitre requiſite to give 159.7 will be 613.2 nearly, and thus the difference with M. Homberg is only about eight grains.

392 Homberg's experiments compared with thoſe of Mr Kirwan.

M. Homberg ſays he found his ſalt, when evaporated to dryneſs, to weigh 186 grains more than before, but by Mr Kirwan's experiment, it ſhould weigh but 92.8 grains more than at firſt; the cauſe of which difference will be mentioned in treating of vitriolated tartar, as it cannot be entirely attributed to the difference of evaporation.

393 Different reſults of Homberg and Kirwan's experiments accounted for.

He alſo aſſerts, that one ounce (472.5 Troy grains) of this ſpirit of nitre contains 141 grains of Troy of real acid. According to Mr Kirwan's computation, however, it contains only 123.08 grains of real acid. But this difference evidently proceeds from his neglecting the quantity of water that certainly enters into the compoſition of nitre; for he proceeds on this analogy, 621 : 186.6 :: 472.5 : 141.

394 Mr Kirwan's experiments confirmed by one of Fontana.

Our author obſerves, that the proportion of fixed alkali aſſigned by him to nitre is fully confirmed by an experiment of Mr Fontana's inſerted in Rozier's Journal for 1773. He decompoſed two ounces of nitre by diſtilling it with a ſtrong heat for 18 hours. After the diſtillation there remained in the retort a ſubſtance purely alkaline, amounting to 10 French drachms and 22 grains. Now two French ounces contain 945 grains Troy, and the alkaline matter 607 grains of the ſame kind: according to Mr Kirwan's computation the two ounces of nitre ought to contain 625 grains of alkali. Such a ſmall difference he ſuppoſes to proceed from the loſs in transferring from one veſſel to another, weighing, filtering, evaporating, *&c.* Mr Kirwan alſo ſhows in a very particular manner the agreement of his calculations with the experiments of M. Lavoiſier on mercury diſſolved in ſpirit of nitre; but our limits will not allow us to inſert an account of them.

When finding the quantity of pure acid contained in oil of vitriol, our author made uſe of ſuch as was not dephlogiſticated; but, though pale, yet a little inclining to red. It contained ſome whitiſh matter, as he perceived by its growing milky on the affuſion of pure diſtilled water; but he imagines it was as pure as the kind uſed in all experiments.

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395 Experiments on oil of vitriol.

To 2519.75 grains of this oil of vitriol, whoſe ſpecific gravity was 1.819, he gradually added 180 grains of diſtilled water, and ſix hours after found its ſpecific gravity to be 1.771.—To this mixture he again added 178.75 grains of water, and found its ſpecific gravity, when cooled to the temperature of the atmoſphere, to be 1.719, at which time it was milky. The ſame quantity of the oil of tartar abovementioned was then ſaturated with each of theſe kinds of oil of vitriol in the manner already deſcribed. The ſaturation was effected (taking a medium of five experiments) by 6.5 grains of that whoſe ſpecific gravity was 1.819, by 6.96 grains of that whoſe ſpecific gravity was 1.771, and by 7.41 of that whoſe ſpecific gravity was 1.719.

396 Dilution of oil of vitriol why neceſſary in theſe experiments.

It was found neceſſary to add a certain proportion of water to each of theſe ſorts of oil of vitriol; for when they were not diluted, part of the acid was phlogiſticated, and went off with the fixed air; but knowing the quantity of water that was added, it was eaſy to find by the rule of proportion the quantity of each ſort of vitriol that was taken up by the alkali. Hence it was ſuppoſed, that each of theſe quantities of oil of vitriol of different denſities contained 3.55 grains of acid; as they ſaturated the ſame quantity of vegetable fixed alkali with 11 grains of ſpirit of nitre, which contained that quantity of acid.

397 To find the ſpecific gravity of pure vitriolic acid.

It was next attempted to find the ſpecific gravity of the pure vitriolic acid in a manner ſimilar to that by which the gravity of the nitrous acid was found; as it cannot be had in the ſhape of air, unleſs when united with ſuch a quantity of phlogiſton as quite alters its properties. The loſs of 6.5 grains of oil of vitriol, whoſe ſpecific gravity is 1.819, is $\frac{6.5}{1.819} = 3.572$; but as theſe 6.5 grains contained, beſides 3.55 of acid, 2.95 of water, the loſs of this muſt be ſubtracted from the entire loſs; and then the remainder, or 0.622, is the loſs of the pure acid part in that ſtate or denſity to which it is reduced by its union with water. The ſpecific gravity, therefore, of the pure vitriolic acid, in this ſtate of denſity, is $\frac{3.55}{0.622} = 5.707$. But to find its natural ſpecific gravity, we muſt find how much its denſity is increaſed by its union with this quantity of water: and in order to obſerve this, he proceeded as before with the nitrous acid. 6.96 grains of oil of vitriol, whoſe ſpecific gravity was 1.771, contained 3.55 of acid and 3.41 of water; then its ſpecific gravity by calculation ſhould be 1.726; for the loſs of 3.55 grains of acid is $\frac{3.55}{5.707} = 0.622$; the loſs of 3.41 grains of water is 3.41; the ſum of the loſſes 4.032: then $\frac{6.96}{4.032} = 17.16$; therefore the accrued denſity is $1.771 - 1.726 = 0.45$. Taking this therefore from 1.819, its mathematical ſpecific gravity will be 1.774. Then the loſs of 6.5 grains of oil of vitriol, whoſe ſpecific gravity by obſervation is 1.819, will be found to be $\frac{6.5}{1.774} = 4.663$; but of this, 2.95 grains are the loſs

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of the water it contains, and the remainder 0.714 are the loſs of the mere acid part. Then $\frac{3.55}{0.714}$ is nearly the true ſpecific gravity of the pure vitriolic acid. The ſpecific gravity of the moſt concentrated oil of vitriol yet made, is, according to M. Baume and Bergman, 2.125.

Mr Kirwan now conſtructed a table of the ſpecific gravities of vitriolic acids, of different ſtrengths, in a manner ſimilar to thoſe conſtructed for ſpirit of ſalt and ſpirit of nitre; but for which, as well as the others, we muſt refer to Phil. Tranſ. vol. 71. He then proceeded to find the proportion of acid, water, and fixed alkali, in vitriolated tartar as he had before done in ſal digeſtivus and nitre.—He found the ſalts reſulting from the ſaturation of the ſame oil of tartar, with portions of oil of vitriol, of different ſpecific gravities, to weigh at a medium 12,45 grains. Of this weight only 11.85 grains were alkali and acid. The remainder, therefore, was water, *viz* 0.6 of a grain. Conſequently 100 grains of perfectly dry tartar vitriolate contain 21.58 grains acid, 4.82 of water, and 66.67 of fixed vegetable alkali.—In drying this ſalt, a heat of 240 degrees was made uſe of, to expel the adhering acid more thoroughly. It was kept in this heat for a quarter of an hour.

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Quantity of acid, alkali, and water, in vitriolated tartar determined

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Difference with Mr Homberg accounted for.

According to Mr Homberg, one French ounce, or 472.5 grains troy, of dry ſalt of tartar, required 297.5 grains troy, of oil of vitriol, whoſe ſpecific gravity was 1.674 to ſaturate it: but by Mr Kirwan's calculation, this quantity of fixed alkali would require 325 grains; a difference which, conſidering the different methods they made uſe of for determining the ſpecific gravities (Homberg's method by menſuration, giving it always leſs than Mr Kirwan's) the different deſiccation of their alkalies, &c. may be accounted inconſiderable.

The ſalt produced, according to Mr Homberg, weighed 182 grains troy above the original weight of the fixed alkali; but by Kirwan's experiment, it ſhould weigh but 87.7 grains more. "It is hard to ſay (adds Mr Kirwan) how Mr Homberg could find this great exceſs of weight, both in nitre and tartar vitriolate; unleſs he meant by the weight of the ſalt of tartar the weight of the mere alkaline part diſtinct from the fixed air it contained: and indeed one would be tempted to think he did make the diſtinction; for in that caſe the exceſs of weight would be nearly ſuch as he determined it."

From Mr Homberg's calculations, he inferred that one ounce (472.5 grains) of oil of vitriol contains 291.7 grains of acid. Mr Kirwan computes the acid only at 213.3 grains; but Homberg made no allowance for the water contained in tartar vitriolate; and imagined the whole increaſe of weight proceeded from the acid that is united in it to the fixed alkali. Now the aqueous part in 560 grains of tartar vitriolate amounts to 36 grains; the remaining difference may be attributed to the different degrees of deſiccation, &c.

400
Specific gravity of the acetous acid.

On the acetous acid Mr Kirwan did not make any experiment; but by calculating from thoſe of Homberg, he finds that the ſpecific gravity of the pure acetous acid, free from ſuperfluous water, ſhould be 2.30. "It is probable (ſays Mr Kirwan), that its affinity to water is not ſtrong enough to cauſe any irregular increaſe in its denſity; at leaſt what can be expreſſed by three decimals: and hence its proportion of acid and water may always be calculated from its ſpecific quantity and abſolute weight."

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An hundred parts of foliated tartar, or, as it ſhould rather be called, acetous tartar, contain, when well dried, 32 of fixed alkali, 19 of acid, and 49 parts of water.—The ſpecific gravity of the ſtrongeſt concentrated vinegar yet made is 1.069.—It is more difficult to find the point of ſaturation with the vegetable than with the mineral acids, becauſe they contain a mucilage that prevents their immediate union with alkalies; and hence they are commonly uſed in too great quantity: they ſhould be uſed moderately hot, and ſufficient time allowed them to unite.

401
Specific gravity of ſtrong vinegar.

402
Vegetable fixed alkali takes up an equal quantity of all the mineral acids.

From all the experiments above related, Mr Kirwan concludes, 1. That the fixed vegetable alkali takes up an equal quantity of the three mineral acids, and probably of all pure acids; for we have ſeen that 8.3 grains of pure vegetable alkali, that is, free from fixed air, take up 3.55 grains of each of theſe acids; and conſequently 100 parts of cauſtic fixed alkali would require 42.4 parts of acid to ſaturate them. But Mr Bergman has found that 100 parts of cauſtic fixed vegetable alkali take up 47 parts of the aerial acid; which, conſidering that his alkali might contain ſome water, differs but little from that already given. It ſhould ſeem, therefore, that alkalies have a certain determined capacity of uniting to acids, that is, to a given weight of acids; and that this capacity is equally ſatiated by a given weight of any pure acid indiſcriminately. This weight is about 2.35 of the vegetable alkali.

403
Quantity of the alkali neceſſary to ſaturate the acids.

2. That the three mineral acids, and probably all pure acids, take up 2.253 times their own weight of pure vegetable alkali, that is, are ſaturated by that quantity.

404
Increaſe of denſity in compound ſubſtances.

3. That the denſity accruing to compound ſubſtances, from the union of their compound parts, and exceeding its mathematical ratio, increaſes from a *minimum*, when the quantity of one of them is very ſmall in proportion to that of the other; to a *maximum*, when their qualities differ leſs: but that the attraction, on the contrary, of that part which is in the ſmalleſt quantity to that which is in the greater, is at its maximum when the accrued denſity is at its minimum; but not reciprocally: and hence the point of ſaturation is probably the maximum of denſity and the minimum of ſenſible attraction of one of the parts. Hence no decompoſition operated by means of a ſubſtance that has a greater affinity with one part of a compound than with the other, and than theſe parts have with each other, can be complete, unleſs the minimum affinity of this third ſubſtance be greater than the maximum affinity of the parts already united. Hence alſo few decompoſitions are complete, unleſs a double affinity intervenes; and hence the laſt portions of the ſeparated ſubſtance adhere ſo obſtinately to that with which it was firſt united, as all chemiſts have obſerved.— Thus, though acids have a greater affinity to phlogiſton than the earths of the different metals have to it, yet they can never totally dephlogiſticate theſe earths but only to a certain degree; ſo, though atmoſpheric air, and particularly dephlogiſticated air, attracts phlogiſton more ſtrongly than the nitrous acid does, yet not even dephlogiſticated air can deprive the nitrous acid totally of its phlogiſton; as is evident from the

405
Why decompoſitions are ſometimes incomplete, and otherwiſe.

406
Why the laſt portions of a ſubſtance obſtinately adhere to that with which it was united.

407
Acids can never totally dephlogiſticate metallic earths.

the red colour of the nitrous acid, when nitrous air and dephlogiſticated air are mixed together. Hence mercury precipitated from its ſolution in any acid, even by fixed alkalies, conſtantly retains a portion of the acid to which it was originally united, as Mr Bayen has ſhown. Thus alſo the earth of alum, when precipitated in like manner from its ſolution, retains part of the acid; and thus ſeveral anomalous decompoſitions may be explained.

408 Why precipitates of mercury and alum retain part of the acid.

409 Alkalies phlogiſticate concentrated acids.

4. That concentrated acids are in ſome meaſure phlogiſticated, and evaporate by union with fixed alkalies.

410 How to determine the quantity of pure acid in any ſubſtance.

5. That, knowing the quantity of fixed alkali in oil of tartar, we may determine the quantity of real pure acid in any other acid ſubſtance that is difficultly decompoſed; as the ſedative acid, and thoſe in vegetables and animals. For 10.5 grains of the mild alkali will always be ſaturated by 3.55 grains of real acid; and reciprocally, the quantity of acid in any acid liquor being known, the quantity of real alkali in any vegetable alkaline liquor may be found.

411 Specific gravity of fixed air determined.

Having thus determined the quantity of acid contained in the liquids of that kind uſually employed in chemiſtry, as well as the ſpecific gravities of the acids themſelves, Mr Kirwan became deſirous of inveſtigating the gravity of fixed and volatile alkalies. But as theſe ſubſtances are not eaſily preſerved from uniting themſelves with fixed air, he was led to conſider the gravity of this in its fixed ſtate, as an element neceſſary for the calculation of the quantities of the alkalies.

412 Specific gravity of fixed vegetable alkali inveſtigated.

To find the ſpecific gravity of the fixed vegetable alkali, our author proceeded in a manner ſimilar to that already deſcribed, excepting that he weighed it in ether inſtead of ſpirit of wine. The reſults of his experiments are.

413 Quantity of earth contained in it.

1. That 100 grains of this alkali contain about 6.7 grains of earth; which, according to Mr Bergman, is ſiliceous. It paſſes the filter along with it when the alkali is not ſaturated with fixed air; ſo that it ſeems to be held in ſolution in the ſame manner as in the *liquor ſilicum*.

414 Quantity of fixed air in oil of tartar and dry vegetable fixed alkali.

2. The quantity of fixed air in oil of tartar and dry vegetable fixed alkali is various at various times, and in various parcels of the ſame ſalt; but in the purer alkalies it may be reckoned at a medium 21 grains in 100; and hence the quantity of this alkali may very nearly be gueſſed at in any ſolution, by adding a known weight of any dilute acid to a given weight of ſuch a ſolution, and then weighing it again; for as 21 is to 100, ſo is the weight loſt to the weight of mild alkali in ſuch ſolution. The ſpecific gravity of mild and perfectly dry vegetable fixed alkali, four times calcined, free from ſiliceous earth, and containing 21 *per cent.* of fixed air, was found to be 5.0527. When it contains more fixed air the gravity is probably higher, except when it is not perfectly dry; and hence the ſpecific gravity of this alkali, when cauſtic, was ſuppoſed by Mr Kirwan to be 4.234. For this reaſon the fixed alkalies, when united to aerial acid, are ſpecifically heavier than when united either to the vitriolic or nitrous. Thus Mr R. Watſon, in the Philoſophical Tranſactions for 1770, informs us, that he found the ſpecific gravity of dry ſalt of tartar, including the ſiliceous earth it naturally contains, to be 2.761; whereas the ſpecific gravity of vitriolated tartar was only 2.636, and that of nitre 1.933. The reaſon why nitre is ſo much lighter than tartar vitriolate is, that it contains much more water, and the union of the acid with the water is leſs intimate.

415 Mr Watſon's account of the ſpecific gravity of ſalt of tartar, &c.

416 Why nitre is ſo much lighter than vitriolated tartar.

Impure vegetable fixed alkalies, ſuch as pearl-aſh, potaſhes, &c. contain more fixed air than the purer kind. According to Mr Cavendiſh, pearl-aſh contains 28.4 or 20.7 *per cent.* of fixed air. Hence in lyes made from theſe ſalts, of equal ſpecific gravities with thoſe of a purer alkali, the quantity of ſaline matter will probably be in the ratio of 28.4 or 28.7 to 21; but this additional weight is only fixed air. Much alſo depends on their age; the oldeſt containing moſt fixed air. Our author alſo gives a table of the ſpecific gravities of different ſolutions of vegetable fixed alkali, in a manner ſimilar to what he had done before with the acids. He begins with 64.92 grains of a ſolution containing 26.25 grains of ſalt, and 38.67 of water. The accrued denſity he finds to be .050, the mathematical ſpecific gravity 1.445, and the ſpecific gravity by obſervation 1.495. By continually diluting the ſolution containing the ſame quantity of ſalt, he brings the abſolute weight of it at laſt to 341.94 grains, of which 317.49 are water; the accrued denſity 0.01, the mathematical ſpecific gravity 1.061, and the ſpecific gravity by obſervation 1.062.

417 Quantity of fixed air in pure vegetable alkalies determined by Mr Cavendiſh.

418 Quantity of acid taken up by mild fixed alkali exactly determined.

In a ſubſequent paper on this ſubject, Philoſophical Tranſactions, vol. 72, p. 179, our author corrects a ſmall miſtake concerning the quantity of acid taken up by 10.5 grains of mild vegetable alkali. In his former computations he had made no allowance for the ſmall quantity of earth contained in this quantity of alkali; which, though inconſiderable in it, becomes of conſequence where the quantities are large. The error, however, occaſioned by this omiſſion, is ſenſible in his calculations concerning the quantities of acid alkali, &c. contained in the neutral ſalts, as well as in that concerning the vegetable alkali. When the correction is properly made, he ſays, it will be found that 100 grains of ſuch alkali, free from earth, water, and fixed air, take up 46.77 of the mineral acids, that is, of the mere acid part; and 100 grains of common mild vegetable alkali take up 36.23 grains of real acid. An hundred grains of perfectly dry tartar vitriolate contain 30.21 of real acid, 64.61 of fixed alkali, and 5.18 of water. Cryſtallized tartar vitriolate loſes only one *per cent.* of water in a heat in which its acid is not ſeparated in any degree; and therefore contains 6.18 of water. An hundred grains of nitre, perfectly dry, contain 30.86 of acid, 66 of alkali, and 3.14 of water; but in cryſtallized nitre the proportion of water is ſomewhat greater; for 100 grains of thoſe cryſtals being expoſed to a heat of 180° for two hours, loſt three grains of their weight without exhaling any acid ſmell; but when expoſed to a heat of 200 degrees, the ſmell of the nitrous acid is diſtinctly perceived. Hence 100 grains of cryſtallized nitre contain 29.89 of mere acid, 63.97 of alkali, and 6.14 of water. An hundred grains of digeſtive ſalt perfectly dry, contain 29.68 of marine acid, 63.47 of alkali, and 6.85 of water. One hundred grains of cryſtallized digeſtive ſalt loſe but one grain of their weight before the ſmell of the marine acid is perceived; and hence they contain 7.85 grains of water.

419 Of the quantity of ingredients in vitriolated tartar;

420 In nitre;

421 In digeſtive ſalt.

Another miſtake, more difficult to be corrected, was his ſuppoſing the mixtures of oil of vitriol and water, and ſpirit of nitre and water, had attained their maximum of denſity when they had cooled to the tempera-

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422 Time required by mixtures of mineral acids and water to acquire their utmost density.

ture of the atmoſphere; which at the time he made the experiment was between 50° and 60° of Fahrenheit. The mixture with oil of vitriol had been ſuffered to ſtand ſix hours; but when the acid was ſo much diluted as to occaſion little or no heat, it was allowed to ſtand only for a very little time. Several months afterwards, however, many of theſe mixtures were found much denſer than when he firſt examined them; and it was diſcovered, that at leaſt twelve hours reſt was neceſſary before concentrated oil of vitriol, to which even twice its weight of water is added, can attain its utmoſt denſity; and ſtill more when a ſmaller proportion of water is uſed. Thus when he made the mixture of 2519.75 grains of oil of vitriol, whoſe ſpecific gravity was 1.819, with 180 of water, he found its denſity ſix hours after 1.771, but after 24 hours it was 1.798: and hence, according to the methods of calculating already laid down, the accrued denſity was at leaſt .064 inſtead of .045. But by uſing oil of vitriol ſtill more concentrated, whoſe ſpecific gravity was 1.8846, he was enabled to make a ſtill nearer approximation; and found, that the accrued denſity of oil of vitriol, whoſe ſpecific gravity is 1.819, amounts to 0.104, and conſequently its mathematical ſpecific gravity is 1.715. Six grains and a half of this oil of vitriol contained, as has been already obſerved, 3.55 of mere acid, and the remainder was water. The weight of an equal bulk of water is 3.79 grains; and ſubtracting from this the weight of the water that enters into the compoſition of the oil of vitriol, it will be found, that the weight of a bulk of water equal to the acid part is 0.84; and conſequently the ſpecific gravity of the mere acid part is 4.226. Thus, by conſtantly allowing the mixtures to reſt at leaſt 12 hours, until the oil of vitriol was diluted with four times its weight of water, and then only ſix hours before the denſity of the mixtures was examined, he conſtructed another table, in which 1000 grains of liquor contained 612.05 of pure acid, 387.95 of water, the accrued denſity being .07, and the mathematical ſpecific gravity 1.877. Increaſing the quantity of water till the acid weighed 7000 grains, and the water 6387.95, he found the accrued denſity .059, and the mathematical ſpecific gravity 1.069. By a ſimilar correction of his experiments on the acid of nitre, he found its denſity to be 5.530; a ſimilar table was conſtructed for it, for which we refer our readers to the 72d volume of the Philoſophical Tranſactions.

423 Alteration of the denſity of acids by various degrees of heat.

These experiments were made when the thermometer ſtood between 50° and 60° of Fahrenheit; but, as it might be ſuſpected that the denſity of acids is conſiderably altered at different degrees of temperature, he endeavoured to find the quantity of this alteration in the following manner: To calculate what this denſity would be at 55°, he took ſome dephlogiſticated ſpirit of nitre, and examined its ſpecific gravity at different degrees of heat; which was found to be as follows,

Degrees of heat.	Specific gravity.
30	1.4653
46	1.4587
86	1.4302
120	1.4123

The total expanſion of this ſpirit of nitre, therefore, from 30 to 120 degrees, that is, by 90° of heat, was 0.0527; for 1.4650=4123+.0527. By which we ſee, that the dilatations are nearly proportional to the degrees of heat: for beginning with the firſt dilatation from 30 to 46 degrees, that is, by 16 degrees of heat, we find that the difference between the calculated and obſerved dilatations is only $\frac{30}{10000}$; a difference of no conſequence in the preſent caſe, and which might ariſe from the immerſion of the cold glaſs-ball filled with mercury in the liquor. In the next caſe the difference is ſtill leſs, amounting only to $\frac{21}{100000}$.

With another, and ſomewhat ſtronger ſpirit of nitre, the ſpecific gravities were as follow:

Degrees of heat.	Specific gravity.
34	1.4750
49	1.4653
150	1.3792

Here alſo the expanſions were nearly proportional to the degrees of heat; for 116° of heat, the difference between 34 and 150, produce an expanſion of 0.0958; and 15° of heat, the difference between 34 and 49, produce an expanſion of 0.0097; and by calculation 0.0123: which laſt differs from the truth only by $\frac{21}{100000}$.

484 Strong ſpirit of nitre more expanded by heat than weak, and why.

From this experiment we ſee, that the ſtronger the ſpirit of nitre is, the more it is expanded by the ſame degree of heat; for if the ſpirit of nitre of the laſt experiment were explained in the ſame proportion as in the former, its dilatation, by 116 degrees of heat, ſhould be 0.0679; whereas it was found to be 0.0958. As the dilatation of the ſpirit of nitre is far greater than that of water by the ſame degree of heat, and as it conſiſts only of acid and water; it clearly follows, that its ſuperior dilatability muſt be owing to the acid part: and hence the more acid that is contained in any quantity of ſpirit of nitre, the greater is its dilatability. We might therefore ſuppoſe, that the dilatation of nitre was intermediate betwixt the quantity of water it contains and that of the acid. But there exiſts another power alſo which prevents this ſimple reſult, *viz.* the attraction of the acid and water to each other, which makes them occupy leſs ſpace than the ſum of their joint volumes; and by this condenſation our author explains his phraſe of *accrued denſity*. Taking this into the account, we may conſider the dilatation of the ſpirit of nitre as equal to thoſe of the quantities of water and acid it contains, minus the condenſation they acquire from their mutual attraction; and this rule holds as to all other heterogeneous compounds.

425 Exact quantity of dilatation of ſpirit of nitre.

426 Of the quantities of acid and water contained in ſpirit of nitre.

To find the quantities of acid and water in ſpirit of nitre, whoſe ſpecific gravity was found in degrees of temperature different from thoſe for which the table was conſtructed, viz. 54°, 55°, or 56° of Fahrenheit, the ſureſt method is to find how much that ſpirit of nitre is expanded or condenſed by a greater or leſſer degree of heat; and then, by the rule of proportion, find what its denſity would be at 55°. But if this cannot be done, we ſhall approach pretty near the truth if we allow $\frac{10}{10000}$ for every 15° degrees of heat above or below 55° of Fahrenheit, when the ſpecific gravity is between 1.409 and 1.500, and $\frac{8}{10000}$ when the ſpecific gravity is between 1.600 and 1.800.—The dilatations of oil and ſpirit of vitriol were found to be exceedingly irregular, probably by reaſon of a white foreign matter, which is more or leſs ſuſpended or diſſolved in it, according to its greater or leſſer dilution; and

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and this matter our author did not separate, as he intended to try the acid in the state in which it is commonly used. In general he found that 15° of heat caused a difference of above $\frac{8}{100}$ in its specific gravity, when it exceeds 1.800, and of $\frac{3}{1000}$ when its specific gravity is between 1.400 and 1.300—The dilatations of spirit of salt are very nearly proportional to the degrees of heat, as appears by the following table.

427 Dilatation of spirit of salt by various degrees of heat.

Degrees of heat.	Specific gravity.
33	1.1916
54	1.1860
66	1.1820
128	1.1631

Hence $\frac{6}{1000}$ should be added or subtracted for every 21° above or below 55°, in order to reduce it to 55°, the degree for which its proportion of acid and water was calculated. The dilatability of this acid is much greater than that of water, and even than that of the nitrous acid of the same density.

428 Quantity of pure acid taken up by various substances.

Our author next proceeds to consider the quantity of pure acids taken up at the point of saturation by the various substances they unite with.—He begins with the mineral alkali. Having rendered a quantity of this caustic in the usual manner, and evaporating one ounce of the caustic solution to perfect dryness, he found it to contain 20.25 grains of solid matter. He was assured, that the watery part alone exhaled during evaporation, as the quantity of fixed air contained in it was very small, and to dissipate this a much greater heat would have been requisite than that which he used. This dry alkali was dissolved in twice its weight of water; and saturating it with dilute vitriolic acid, he found it to contain 2.25 grains of fixed air; that being the weight which the saturated solution wanted of being equal to the joint weights of water, alkali, and spirit of vitriol employed.

429 Mineral alkali how prepared for these experiments.

430 Quantity of vitriolic acid necessary to saturate it.

The quantity of mere vitriolic acid necessary to saturate 100 grains of pure mineral alkali was found to be 60 or 61 grains; the saturated solution thus formed being evaporated to perfect dryness weighed 36.5 grains; but of this weight only 28.38 were alkali and acid; the remainder, that is, 8.12 grains, therefore, were water. Hence 100 grains of Glauber's salt, perfectly dried, contained 29.12 of mere vitriolic acid, 48.6 of mere alkali, and 22.28 of water. But Glauber's salt crystallized contains a much larger proportion of water; for 100 grains of these crystals heated red hot lost 55 grains of their weight; and this loss Mr Kirwan supposes to arise merely from the evaporation of the watery part, and the remaining 45 contained alkali, water, and acid, in the same proportion as the 100 grains of Glauber's salt perfectly dried abovementioned. Then these 45 contained 13.19 grains of vitriolic acid, 21.87 of fixed alkali, and 9.94 of water: consequently 100 grains of crystallized Glauber's salt contains 13.19 of vitriolic acid, 21.87 of alkali, and 64.94 of water.

431 Quantity of ingredients in Glauber's salt.

432 Quantity of mineral alkali taken up by dephlogisticated nitrous acid;

On saturating the mineral alkali with dephlogisticated nitrous acid, it was found that 100 grains of the alkali took up 57 of the pure acid in the experiment he most depended upon; though in some others this quantity varied by a few grains: he concludes, therefore, that the quantity of alkali taken up by this acid is nearly the same as that taken up by the vitriolic. Supposing this quantity to be 57 grains, then 100 grains of cubic nitre, perfectly dry, contain 30 of acid, 52.18 of alkali, and 17.82 of water: but cubic nitre crystallized contains something more water; for 100 grains of these crystals lose about four by gentle drying; therefore 100 grains of the crystallized salt contain 28.8 of acid, 50.09 of alkali, and 21.11 of water.

433 By marine acid.

An hundred grains of mineral alkali require from 63 to 66 or 67 grains of pure marine acid to saturate it; but Mr Kirwan supposes that one reason of this variety is, that it is exceeding hard to hit the true point of saturation. Allowing 66 grains to be the quantity required, then 100 grains of perfectly dry common salt contain nearly 35 grains of real acid, 53 of alkali, and 13 of water; but 100 grains of the crystallized salt lose five by evaporation; so that 100 grains of these crystals contain 33.3 of acid, 50 of alkali, and 16.7 of water.

434 Proportion of fixed air, alkali, and water, investigated by this saturation.

The proportion of fixed air, alkali, and water, was thus investigated: 200 grains of these crystals were dissolved in 240 of water; the solution was saturated by such a quantity of spirit of nitre as contained 40 of pure nitrous acid; whence it was inferred that these 200 grains of salt of soda contained 70 of pure alkaline salt. The saturated solution weighed 40 grains less than the sum of its original weight, and that of the spirit of nitre added to it; consequently it lost 40 grains of fixed air. The remainder of the original weight of the crystals therefore must have been water, *viz.* 90 grains. Consequently 100 grains of these crystals contained 35 of alkali, 20 of fixed air, and 45 of water. This proportion differs considerably from that assigned by Mr Bergman and Lavoisier, which our author imputes to their having made use of soda recently crystallized; but Mr Kirwan's had been made for some months, and probably lost much water and fixed air by evaporation, which altered the proportion of the whole. According to the calculations of Bergman and Lavoisier, 100 grains of this alkali take up 80 of fixed air. The specific gravity of the crystallized mineral alkali, weighed in ether, found to be 1.421.

435 Differences with M. Bergman and Lavoisier accounted for.

436 Proportions of ingredients in volatile alkalies.

The proportion of the different ingredients in volatile alkalies can only be had from the experiments lately made by Dr Priestley concerning alkaline air. He informs us, that $\frac{6}{10}$ of a measure of this, and one measure of fixed air, saturate one another. Then, supposing the measure to contain 100 cubic inches, 185 cubic inches of alkaline air take up 100 of fixed air; but 185 cubic inches of alkaline air weigh at a medium 42.55 grains, and 100 cubic inches of fixed air weigh 57 grains; therefore 100 grains of pure volatile alkali, free from water, take up 134 of fixed air.

On expelling its aerial acid from a quantity of this volatile alkali in a concrete state, and formed by sublimation, he found, that 53 grains of it were fixed air: according to the preceding calculation, 100 grains of it should contain 39.47 of real alkali, and 7.53 of water, the rest being fixed air.—On saturating a quantity with the vitriolic, nitrous, and marine acids, 100 grains of the mere alkali were found to take up 106 of mere vitriolic acid, 115 of the nitrous, and 130 of the marine acid. The specific gravity of the volatile alkali

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alkali weighed in ether (B) was 1.4076. The proportion of water in the different ammoniacal ſalts could not be found on account of their volatility; but was ſuppoſed to be very ſmall, as both volatile alkali and fixed air cryſtallize without the help of water when in an aerial ſtate.

437 Experiments on calcareous earth.

In making experiments on calcareous earth, it was firſt diſſolved in nitrous acid; and after allowing for the loſs of fixed air and water, 100 grains of the pure earth was found to take up 104 of nitrous acid; but only 91 or 92 of mere vitriolic acid were required to precipitate it from the nitrous ſolution.

438 Quantity of marine acid ſaturated by this earth.

Of the marine acid 100 grains of the pure calcareous earth require 112 for their ſolution. The liquor at firſt is colourleſs, but acquires a greeniſh colour by ſtanding.

439 Proportion of ingredients in natural gypſum;

Natural gypſum varies in its proportion of acid, water, and earth; 100 grains of it containing from 32 to 34 of acid and likewiſe of earth, and from 26 to 32 of water. The artificial gypſum contains 32 of earth, 29.44 of acid, and 38.56 of water. When well dried, it loſes about 24 of water; and therefore contains 42 of earth, 39 of acid, and 19 of water, *per* hundred.

440 In nitrous ſelenite;

Nitrous ſelenite (ſolution of calcareous earth in nitrous acid) carefully dried, contains 33.28 of acid, 32 of earth, and 34.72 of water.

441 In marine ſelenite.

The ſame quantity of marine ſelenite (ſolution of calcareous earth in marine acid), well dried, in ſuch a manner as to loſe no part of the acid, contain of the latter 42 56, of earth 38, and of water 19.44.

442 Calcined magneſia will not diſſolve in acids without heat.

Magneſia, when perfectly dry and free from fixed air, cannot be diſſolved in any of the acids without heat. Even the ſtrongeſt nitrous acid did not act upon it in 24 hours in the temperature of the atmoſphere; but in a heat of 180°, the mineral acids, diluted with four, or even ſix, times their quantity of water, had a very ſenſible effect upon it; but the quantity of acid diſſipated by heat rendered it impoſſible to aſcertain how much was neceſſary for ſolution, except by precipitation after it had been diſſolved. For this purpoſe the cauſtic vegetable alkali was employed; by which it appeared that 100 grains of pure magneſia take up 125 of mere vitriolic acid, 132 of the nitrous, and 140 of the marine. All of theſe ſolutions appeared to contain ſomething gelatinous; but none of them reddened vegetable blues; and that in the marine acid became greeniſh on ſtanding for ſome time.

443 Proportion of the ingredients in common Epſom ſalt;

An hundred grains of perfectly dry Epſom ſalt contain 45.67 of mere vitriolic acid, 36.54 of pure earth, and 17.83 of water. Solution of common Epſom ſalt, however, reddens vegetable blues, and therefore contains an exceſs of acid.

444 In nitrous Epſom.

A like quantity of nitrous Epſom, well dried, contains 35.64 of acid, 27 of pure earth, and 37.36 of water.

445 Cannot be found in marine Epſom.

The ſolution of marine Epſom cannot be tolerably dried without loſing much of its acid together with the water. The ſpecific gravity of this earth is 2.3296.

446 Earth of alum contains a great quantity of fixed air.

Moſt writers on chemiſtry have ſaid that earth of alum contains ſcarce any fixed air; but Mr Kirwan found that it contained no leſs than 26 *per cent.* though it had been previouſly kept red-hot for half an hour. It diſſolved with a moderate effervеſcence in acids until the heat was raiſed to 220°; after which the ſolution was found to have loſt weight in the proportion abovementioned.

447 Quantity of ingredients in alum.

An hundred grains of this earth, deprived of the fixed air, require 133 of the pure vitriolic acid to diſſolve them. The ſolution was made in a very dilute ſpirit of vitriol, whoſe ſpecific gravity was 1.093, and in which the proportion of acid to the water was nearly as 1 to 14. It contained a ſlight exceſs of acid, turning the vegetable blues to a browniſh red; but it cryſtallized when cold, and the cryſtals were of the form of alum. Our author, therefore, is of opinion, that this is the true proportion of acid and earth to be uſed in the formation of that ſalt, though there was not water enough to form large cryſtals.

448 This ſalt always contains an exceſs of acid.

Perceiving that the liquor contained an exceſs of acid, more earth was added; but thus it was found impoſſible to prevent it from tinging vegetable blues of a red colour until a precipitation was formed: and even when this was the caſe, though one part of the ſalt fell in the form juſt mentioned, yet the reſt would ſtill redden vegetable blues as before; though here our author doubts whether this be a mark of acidity. An hundred grains of alum, when dried, contain 42.74 of acid, 32.14 of earth, and 25.02 of water; but cryſtallized alum loſes 44 *per cent.* by deſiccation: therefore 100 grains of it contain 23.94 of acid, and 58.06 of water.

449 Proportion of pure earth of alum taken up by nitrous acid;

An hundred grains of this pure earth take up, as near as can be judged, 153 of pure nitrous acid. The ſolution ſtill reddened vegetable blues; but after the above quantity of earth was added, an inſoluble ſalt began to precipitate. The ſolution, when cold, became turbid, and could not be rendered quite clear by 500 times its quantity of water.

450 By marine acid.

An hundred and ſeventy-three grains of pure marine acid are required for the diſſolution of 100 grains of earth of alum, but the liquor ſtill reddened vegetable blues. After this an inſoluble ſalt was formed; but it is difficult to aſcertain the beginning of its formation preciſely both in this and the preceding caſes. The ſpecific gravity of pure argillaceous earth, containing 25 *per cent.* of fixed air, is 1.9901.

451 Experiments on metals.

In the experiments made by our author on metals, the acids employed were ſo far dephlogiſticated as to be colourleſs; the metals were for the moſt part reduced to filings, or to fine powder in a mortar.

452 Beſt method of diſſolving them.

They were added by little and little to their reſpective menſtrua; much more being thus diſſolved than if the whole had been thrown in at once, and the ſolution was performed in glaſs vials with bent tubes.

453 Proportion of iron taken up by the vitriolic acid.

An hundred grains of bar-iron, in the temperature of 56°, require for their ſolution 190 grains of the real acid, whoſe proportion to that of the water, with which it ſhould be diluted, is as 1 to 8, 10, or 12. It would act on iron, though its proportion were greater or leſſer, though not ſo vigorouſly; but by applying a heat of 200° towards the end, 123 grains of

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(B) The fixed and volatile alkalies were weighed in ether on account of their great ſolubility in water.

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of real acid would be ſufficient. The air produced by this ſolution is entirely inflammable, and generally amounts to 115 cubic inches.

454 Quantity of inflammable air produced.

By the aſſiſtance of a ſtrong heat, iron is alſo ſoluble in the concentrated vitriolic acid, though in ſmaller quantity; and inſtead of inflammable air, a large quantity of vitriolic air is produced, and a little ſulphur is ſublimed towards the end.

455 Why vitriolic air is produced by diſſolving iron in concentrated oil of vitriol.

The reaſon of this is, that the concentrated vitriolic acid, containing much leſs ſpecific fire than the dilute kind, cannot expel the phlogiſton in the form of inflammable air (which abſorbs a vaſt quantity of fire), but unites with it when further dephlegmated by heat, and thus forms both vitriolic air and ſulphur. An hundred grains of iron diſſolved without heat afford more than 400 of vitriol; and 100 grains of vitriol, when cryſtallized, contain 25 of iron, 20 of real acid, and 55 of water. When calcined nearly to redneſs, theſe cryſtals loſe about 40 *per cent.* of water.

456 Solution of the calces of iron in vitriolic acid.

The calces of iron are ſoluble in the vitriolic acid according to the quantity of phlogiſton they contain; the more phlogiſticated being more readily ſoluble, and thoſe which are dephlogiſticated leſs ſo. The latter not only require more real acid for their ſolution, but afford only a thick liquor or magma by evaporation, inſtead of cryſtals like the others.

457 That of the dephlogiſticated calces of iron refuſes to cryſtallize.

Hence alſo ſolutions of iron, when newly made, diminiſh, and conſequently phlogiſticate, the ſuperincumbent air by their gradual emiſſion of phlogiſton; at the ſame time that the calx, becoming more and more dephlogiſticated, gradually falls to the bottom, unleſs more acid be added to keep it in ſolution.

458 Proportion of iron diſſolved in nitrous acid.

An hundred grains of iron require for their ſolution in nitrous acid 142 grains of real acid, ſo diluted that its proportion to water ſhould be as 1 to 13 or 14; and when this laſt proportion is uſed, the heat of a candle may be employed for a few ſeconds, and the acceſs of common air prevented. Thus about 18 cubic inches of nitrous air are produced, the reſt being abſorbed by the ſolution, and no red vapours appear. But if the proportion of acid and water be as 1 to 8 or 10, a much greater quantity of metal will be dephlogiſticated by the application of heat, though very little of it be held in ſolution

459 Quantity of nitrous air obtained from this ſolution.

Thus, from 100 grains of iron Mr Kirwan has obtained 83.87 cubic inches of nitrous air; and by diſtilling the ſolution, a ſtill greater quantity may be obtained which had been abſorbed.

460 Why no inflammable air is here produced.

The reaſon that nitrous ſolutions of iron or other metals yield no inflammable air is, becauſe this acid has leſs affinity to water, and more to phlogiſton, than the vitriolic, and likewiſe contains much leſs fire than either that or the marine (ſee n° 278); and therefore unites with phlogiſton, inſtead of barely expelling it.

461 Vitriolic acid acts on iron in a much more dilute ſtate than nitrous.

Hence alſo the vitriolic acid, though united with 30 times its weight of water, will ſtill viſibly act on iron, and ſeparate inflammable air in the temperature of 55°; whereas nitrous acid, diluted with 15 times its weight of water, has no perceptible effect on the metal in that temperature. The calces of iron, if not too much dephlogiſticated, are alſo ſoluble in the nitrous acid.

462 Iron taken up by the marine acid.

Two hundred and fifteen grains of real marine acid are required for the ſolution of 100 grains of iron. When the proportion of water to the acid is as four to one, it effervesces rather too violently with the metal; and heat is rather prejudicial, as it volatilizes the acid. No marine air flies off; and the quantity of inflammable air is exactly the ſame as with diluted vitriolic acid.

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463 Calces of iron precipitated of a reddiſh colour from their ſolution in marine acid.

The calces of iron are alſo ſoluble in marine acid, and may be diſtinguiſhed by their reddiſh colour when precipitated by fixed alkalies, while the precipitates of the metal are greeniſh.

464 Proportion of copper diſſolved by vitriolic acid.

An hundred and eighty-three grains of real vitriolic acid are required to diſſolve an hundred grains of copper; the proportion of acid to that of water being as 1 to 1.5, or at leaſt as 1 to 1.7; and a ſtrong heat muſt alſo be applied. Mr Kirwan ſays he never could diſſolve the whole quantity of copper; but to diſſolve a given quantity of it, a ſtill greater heat muſt be employed in the proportion of 28 to 100; but this reſiduum alſo is ſoluble by adding more acid. Copper dephlogiſticated in this manner is ſoluble by adding warm water to the maſs.

465 Inflammable and vitriolic acid air obtained from ſolution of copper in vitriolic acid.

By treating 128 grains of copper in this manner, we obtain 1.1 cubic inches of inflammable air and 65 of vitriolic acid air. When inflammable air was obtained, however, our author tells us the acid was a little more aqueous. The reaſon why copper cannot be dephlogiſticated by dilute vitriolic acid, or even by the concentrated kind without the aſſiſtance of heat, is its ſtrong attraction to phlogiſton, and the great quantity it contains.

466 Why this metal cannot be acted upon by dilute vitriolic acid.

An hundred grains of vitriol of copper contain 27 of metal, 30 of acid, and 43 of water; 28 of which laſt are loſt by evaporation or ſlight calcination. An hundred grains of copper, when diſſolved, afford 373 of blue vitriol.

467 Proportion of ingredients in blue vitriol.

An hundred grains of copper require 130 of pure nitrous acid for their diſſolution. If the acid be ſo far diluted that its proportion of water be as 1 to 14, the aſſiſtance of heat will be neceſſary, but not otherwiſe. This ſolution affords 67¼ inches of nitrous air.—The calces of copper are ſoluble in the nitrous acid.

468 Quantity of copper diſſolved by nitrous acid.

A like quantity of this metal requires 1190 grains of real marine acid, as well as the aſſiſtance of a moderate heat, to diſſolve them; the proportion of water being as 4½ to 1. By employing a greater heat, more of the acid will be requiſite, as much more will be diſſipated: the concentrated acid acts more vigorouſly.—Calces of copper are likewiſe ſoluble in the marine acid, though leſs eaſily than in the nitrous.

469 In marine acid.

470 Action of the vitriolic acid in tin.

The vitriolic acid diſſolves tin but in ſmall quantity; an hundred grains of the metal requiring for their ſolution 872 of real acid, whoſe proportion to water ſhould not be leſs than 1 to 0.9. A ſtrong heat is alſo required. When the action of the acid has ceaſed, ſome hot water ſhould be added to the turbid ſolution, and the whole again heated. The metal is ſoluble in a more dilute acid, but not in ſuch quantity.—The ſolution abovementioned affords 70 cubic inches of inflammable air.—The calces of tin, excepting that precipitated from marine acid by fixed alkalies, are inſoluble in the vitriolic acid.

471 Inflammable air obtained from the ſolution.

472 Tin diſſolved in nitrous acid.

An hundred grains of tin require 1200 of real nitrous acid; whoſe proportion of water ſhould be at leaſt 25 to 1, and the heat employed not exceeding 60°. The quantity of air afforded by ſuch ſolution is only 10 cubic inches, and it is not nitrous. The ſolution

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lution is not permanent; for in a few days it depofites a whitifh calx, and in warm weather burfts the vial. The calces of tin are infoluble in this acid.

473 In marine acid. Four hundred and thirteen grains of pure marine acid are required to diffolve 100 grains of tin, the proportion of water being as $4\frac{1}{7}$ to 1. The affiftance of a moderate heat is alfo required. About 90 cubic inches of inflammable, and 10 of marine air, are afforded by the folution; but the calces of tin are nearly infoluble in this acid.

474 Lead with vitriolic acid. An hundred grains of lead require 600 grains of real vitriolic acid for their folution, the proportion being not lefs than 1 of acid to $\frac{7}{10}$ of water; and it will ftill be better if the quantity of water be lefs: for which reafon, as in copper, a greater quantity of metal fhould be employed than what is expected to be diffolved. A ftrong heat is alfo requifite; and hot water fhould be added to the calcined mafs, though in

475 Scarce foluble in dilute vitriolic acid. fmall quantity, as it occafions a precipitation.—This metal is alfo foluble, but very fparingly, in dilute vitriolic acid. Its calces are fomething more foluble. An hundred grains of vitriol of lead, formed by precipitation, contain 73 of lead, 17 of real acid, and 10 of water.

476 With nitrous acid. With fpirit of nitre, 78 grains of real acid are required for the folution of 100 of lead, with the affiftance of heat towards the end. The proportion of acid to that of water may be about 1 to 11 or 12. This folution produces but eight cubic inches of air, which is nitrous. The calces of the metal are foluble in this acid; but lefs fo when much dephlogifticated. An hundred grains of minium require 81 of real acid. An hundred grains of nitrous falt of lead contain about 60 of the metal.

477 With marine acid. Six hundred grains of the real marine acid are required for the folution of 100 grains of lead; the fpecific gravity of the acid being 1.141, though more would be diffolved by a ftronger acid.—The calces of lead are more foluble in this acid than the metal itfelf. An hundred grains of minium require 327 of real acid; but white lead is much lefs foluble. The fame quantity of plumbum corneum, formed by precipitation, contain 72 of lead, 18 of marine acid, and 10 of water.

478 Silver with vitriolic acid. An hundred grains of filver require 520 of real vitriolic acid to diffolve them; the proportion of acid to water being not lefs than as 1 to $\frac{8}{10}$: and when fuch a concentrated acid is ufed, it acts flightly even in the temperature of 60°; but a moderate heat is required in order to procure a copious folution. The calces of filver formed by precipitation from the nitrous acid with fixed alkalies are foluble even in dilute vitriolic acid without the affiftance of heat. An hundred grains of vitriol of filver, formed by precipitation, contain 74 grains of metal, about 17 of real acid, and 9 of water.

479 With nitrous acid. An hundred grains of the pureft filver require for their folution 36 of nitrous acid, diluted with water in the proportion of one part of real acid to fix of water, applying heat only when the folution is almoft faturated. If the fpirit be much more or much lefs dilute, it will not act without the affiftance of heat. The laft portions of filver thus taken up afford no air. Standard filver requires about 38 grains of real acid to diffolve the fame proportion of it; and the folution affords 20 cubic inches of nitrous air; whereas 100 grains of filver revived from luna cornea afford about 14.

Mr Kirwan has never been able to diffolve filver in the marine acid, though Mr Bayen fays he effected the diffolution of three grains and a half of it by digeftion fome fome days with two ounces of ftrong fpirit of falt. Newman informs us alfo, that leaf-filver is corroded by the concentrated marine acid. It is diffolved, however, by the dephlogifticated fpirit of falt, as well as by the phlogifticated acid when reduced to a ftate of vapour. An hundred grains of luna cornea contain 75 of filver, 18 of acid and 7 of water. 480 Of the diffolution of filver in marine acid.

Mr Kirwan found that kind of aqua regia to fucceed beft in the diffolution of gold, which was prepared by mixing together three parts of the real marine acid with one of the nitrous acid. Both of them ought alfo to be as concentrated as poffible; though, when this is the cafe, it is almoft impoffible to prevent a great quantity from efcaping, as a violent effervefcence takes place for fome time after the mixture. Aqua regia made with common falt or fal ammoniac and fpirit of nitre, is much lefs aqueous than that proceeding from an immediate combination of both acids; and hence it is the fitteft for producing cryftals of gold. Very little air is produced by the folution of this metal, and the operation goes on very flow. It is, however, better promoted by allowing it fufficient time, than by applying heat. An hundred grains of gold require for their folution 246 grains of real acid, the two acids being in the proportion abovementioned. Though foluble in the dephlogifticated marine acid, it is only in very fmall quantity, unlefs the acid be in a ftate of vapour; for, in its liquid ftate it is too aqueous. In vitriolic and nitrous acids it is infoluble, tho' the calces are fomewhat foluble in the nitrous. more eafily in the marine, but fcarcely at all in the vitriolic acid. Mr Kirwan fays, that gold in its metallic ftate may be diffufed through the concentrated nitrous acid, but not diffolved in it; contrary to the opinion of other chemifts, who have affirmed that a true diffolution takes place. 481 Beft kind of aqua regia for diffolving gold. 482 Quantity of gold taken up by aqua regia. 483 Calces of gold foluble in the vitriolic and nitrous acids. 484 Gold cannot, according to Kirwan, be diffolved in nitrous acid.

An hundred grains of mercury require for their folution 230 grains of real vitriolic acid, whofe proportion to that of water is as 1 to $\frac{8}{10}$. A ftrong heat is alfo requifite, and the air produced is vitriolic. Precipitate *per fe* is ftill lefs foluble.—An hundred grains of vitriol of mercury, produced by precipitation, contain 77 of metal, 19 of acid, and 4 of water. 485 Mercury with vitriolic acid.

In fpirit of nitre, 100 grains of mercury are diffolved by 28 of real acid, whofe proportion to the water it contains is as 1 to $1\frac{54}{100}$. In this acid the folution takes place without heat; but it may alfo be diffolved in a much more dilute acid, provided heat be applied. About 12 cubic inches of air are produced when heat is not applied; but M. Lavoifier found the produce much greater. This, fays Mr Kirwan. was evidently caufed by his ufing red or yellow fpirit of nitre, which already contains much phlogifton. Precipitate *per fe* is much lefs eafily diffolved in the nitrous acid, which Mr Kirwan fuppofes to be owing to the attraction of the aerial acid. 486 With fpirit of nitre.

The marine acid, in its common-phlogifticated ftate, does not act on mercury, at leaft in its ufual ftate of concentration; though M. Homberg, in the Paris Memoirs for the year 1700, affirms, that he diffolved it by feveral months digeftion in this acid. When dephlogifticated, it certainly acts upon it, though very 2d 486 With marine acid.

 weakly

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weakly while in a liquid ſtate. Precipitate *per ſe* is alſo ſoluble in the marine acid with the aſſiſtance of heat. An hundred grains of corroſive ſublimate contain 77 of mercury, 16 of real acid, and ſix of water. The like quantity of mercurius dulcis contains 86 of metal and 14 of acid and water.

487 Zinc with vitriolic acid;

Zinc requires for its ſolution an equal quantity of real vitriolic acid, whoſe proportion to that of water may be as 1 to 8, 10, or 12. Heat muſt be applied towards the end, when the ſaturation is almoſt completed. By the help of heat alſo this ſemimetal is ſoluble in the concentrated vitriolic acid, but a ſmall quantity of black powder remains in all caſes undiſſolved. An hundred cubic inches of inflammable air are produced. An hundred grains of vitriol of zinc contain 20 of zinc, 22 of acid, and 58 of water. The calces of zinc, if not exceedingly dephlogiſticated, are alſo ſoluble in this acid.

488 With nitrous acid.

An hundred and twenty-five grains of real nitrous acid, whoſe proportion to water is that of 1 to 12, are required for the ſolution of 100 grains of this ſemimetal, applying heat ſlightly from time to time.

489 Leſs metal diſſolved by concentrated than by diluted nitrous acid.

A concentrated acid diſſolves leſs of the metal, as a great quantity of the menſtruum eſcapes during the effervеſcence. No nitrous air can be procured, the acid being partly decompoſed during the operation. The calces of zinc, if not too much dephlogiſticated, are likewiſe diſſolved by the nitrous acid.

490 With marine acid.

An hundred grains of zinc, require for their diſſolution 210 grains of real marine acid, the proportion of it to the water being as 1 to 9. If a more concentrated ſpirit of ſalt be made uſe of, a conſiderable part of it will be diſſipated during the effervеſcence, and conſequently more will be required for the ſolution. The calces of zinc are alſo ſoluble in the marine acid.

491 Biſmuth ſcarce ſoluble in vitriolic acid.

Only three grains of biſmuth were diſſolved by 200 of oil of vitriol, whoſe ſpecific gravity was 1.863, though a ſtrong heat was uſed at the ſame time. A greater quantity was indeed ſlightly dephlogiſticated; but when the gravity of the acid was reduced to 1.200, only a ſingle grain of the metal was diſſolved by 400 of it. The calces of this ſemimetal are much more ſoluble. Four cubic inches of vitriolic air were afforded by the ſolution of three grains of biſmuth.

492 Quantity diſſolved in ſpirit of nitre.

In ſpirit of nitre, 100 grains of real acid are only required to diſſolve 100 grains of the metal. The proportion of water to the acid ought to be as 8 or 9 to 1; in which caſe a gentle heat may be applied. The ſolution affords 44 cubic inches of nitrous air. The calces of biſmuth are alſo ſoluble in this acid.—

493 Scarce ſoluble in marine acids.

Only three or four grains of it were diſſolved by 400 of marine acid, whoſe ſpecific gravity was 1.220.

2d 493 Nickel with vitriolic acid;

About four grains of nickel were diſſolved in an hundred of the concentrated vitriolic acid with the aſſiſtance of a ſtrong heat; but its calces are much more ſoluble.—

494 With nitrous acid.

An hundred grains of nickel require for their ſolution 112 of real nitrous acid, whoſe proportion to water is as 1 to 11 or 12. The product of nitrous air is 79 inches. The calces are alſo ſoluble. A moderate heat is neceſſary for the diſſolution of the metal; but a concentrated acid acts ſo rapidly, that much of it is diſſipated.—Only four or five grains of nickel are diſſolved by 200 of ſpirit of ſalt whoſe ſpecific gravity was 1.220. An acid of this degree of ſtrength acts without the aſſiſtance of heat, though a weaker acid requires it, and diſſolves ſtill leſs of the metal. The calces of nickel are alſo ſoluble with difficulty in this acid.

495 With marine acid;

496 Cobalt with vitriolic acid;

Four hundred and fifty grains of real vitriolic acid, whoſe proportion to water is not leſs than 1 to $\frac{7}{16}$, are required for the diſſolution of 100 grains of cobalt, aſſiſted by a heat of 270° at leaſt. A ſolution is obtained by pouring warm water on the dephlogiſticated maſs.—The calces of cobalt, however, are more ſoluble; ſo that even a dilute acid will ſerve.—

497 With ſpirit of nitre;

In ſpirit of nitre, the like quantity of cobalt requires 220 grains of real acid, whoſe proportion to water is as 1 to 4; giving a heat of 180 towards the end.—The calces of the metal are ſoluble in the nitrous acid.—

498 With ſpirit of ſalt;

An hundred grains of ſpirit of ſalt, whoſe ſpecific gravity is 1.178, diſſolves, with the aſſiſtance of heat, two grains and a half of cobalt; and a greater quantity will be diſſolved by an acid more highly concentrated.—The calces of cobalt are more ſoluble.

499 Regulus of antimony with vitriolic acid;

An hundred grains of regulus of antimony require for their ſolution 725 grains of real vitriolic acid, whoſe proportion to water is as 1 to $\frac{7}{16}$, aſſiſted by a heat of 400°. A large quantity of regulus ſhould be put into the acid; and the reſulting ſalt requires much water to diſſolve it, as the concentrated acid lets fall much when water is added to it. A leſs concentrated acid will likewiſe diſſolve this ſemimetal, but in ſmaller quantity. The calces of antimony, even diaphoretic antimony, are ſomewhat more ſoluble.

500 With nitrous acid.

Nine hundred grains of real nitrous acid are required for the ſolution of 100 grains of regulus; the proportion of acid to the water of the ſolvent being as 1 to 12, and aſſiſted by an heat of 110°; but the ſolution becomes turbid in a few days. The calces are much leſs ſoluble in this acid.—

501 Scarce ſoluble in the marine acid.

Only one grain of the regulus is diſſolved by 100 of ſpirit of ſalt, whoſe ſpecific gravity was 1.220, with the aſſiſtance of a ſlight heat; and that which is only 1 178 diſſolves ſtill leſs; but Mr Kirwan is of opinion that the concentrated acid would, in a long time, and by the aſſiſtance of a gentle heat, diſſolve much more. The calces diſſolve more eaſily in the marine acid.

502 Regulus of arſenic with vitriolic acid;

Eighteen grains of regulus of arſenic are diſſolved in a heat of 250° by 200 grains of real vitriolic acid, whoſe ſpecific gravity is 1.871. About ſeven of theſe parts cryſtallize on cooling, and are ſoluble in a large quantity of water. The calces of arſenic are more ſoluble in this acid.—

503 With nitrous acid;

An hundred and forty grains of real nitrous acid are requiſite for the ſolution of 100 grains of regulus of arſenic; the proportion of acid to the water being as 1 to 11. The ſolution affords 102 cubic inches of nitrous air, the barometer being at 30 and the thermometer at 60. Calces of arſenic are likewiſe ſoluble in this acid.

504 With ſpirit of ſalt.

An hundred grains of ſpirit of ſalt, whoſe ſpecific gravity is 1.220, diſſolve a grain and an half of regulus of arſenic; but the marine acid, in its common ſtate, that is, when its gravity is under 1.17, does not at all affect it. The arſenical calces are leſs ſoluble in this than in the vitriolic or nitrous acids.

§ 3. *Of the Quantity of Phlogiſton contained in different Subſtances.*

Having gone through all the various baſes with which acids are uſually combined, and aſcertained the quantity

Quantity of Phlogiston in different Substances.

quantity of different ingredients contained in the compounds resulting from their union, we ought next to give an account of our author's experiments on phlogiston; but as his sentiments on that subject are taken notice of elsewhere, we shall content ourselves with briefly mentioning the very ingenious methods by which he discovers the quantities of it contained in various kinds of air and in sulphur.

505
Quantity of phlogiston contained in nitrous air.

Having proved that inflammable air, in its concrete state, and phlogiston are the same thing, Mr Kirwan proceeds to estimate the quantity contained in nitrous air in the following manner.

"An hundred grains of filings of iron, dissolved in a sufficient quantity of very dilute vitriolic acid, produced, with the assistance of heat gradually applied, 155 cubic inches of inflammable air; the barometer being at 29.5, and the thermometer between 50° and 60°. Now, inflammable air and phlogiston being the same thing, this quantity of inflammable air amounts to 5.42 grains of phlogiston.—Again, 100 grains of iron dissolved in dephlogisticated nitrous acid, in a heat gradually applied and raised to the utmost, afford 83.87 cubic inches of nitrous air. But as this nitrous air contains nearly the whole quantity of phlogiston which iron will part with (it being more completely dephlogisticated by this than any other means), it follows, that 83,87 cubic inches of nitrous air contain at least 5.42 grains of phlogiston. But it may reasonably be thought, that the whole quantity of phlogiston which iron will part with is not expelled by the vitriolic acid, but that nitrous acid may expel and take up more of it. To try whether this was really the case, a quantity of green vitriol was calcined until its basis became quite insipid; after which two cubic inches of nitrous air were extracted from 64 grains of this ochre; and consequently 100 grains, would yield 3.12 cubic inches of nitrous air. If 83.87 cubic inches of nitrous air contain 5.42 of phlogiston; then 3.12 cubic inches of this air contain 0.2 of phlogiston. The nitrous acid, therefore, extracts from 100 grains of iron two-tenths of a grain more phlogiston than vitriolic acid does. Therefore 83.87 cubic inches of nitrous air, containing nearly the whole phlogiston of the iron, have 5.62 of this substance. Hence 100 cubic inches of nitrous air contain 6.7 grains of phlogiston."

2d 505
Quantity of phlogiston in fixed air;

With regard to the quantity of phlogiston in fixed air, after proving at length that it is composed of dephlogisticated air united to the principle of inflammability, Mr Kirwan ascertains the quantity of the latter in the following manner: "Dr Priestley, in the fourth volume of his Observations, p. 380, has satisfactorily proved, that nitrous air parts with as much phlogiston to common air, as an equal bulk of inflammable does when fixed in the same proportion of common air. Now, when inflammable air unites with common air, its whole weight unites to it, as it contains nothing else but pure phlogiston. Since, therefore, nitrous air phlogisticates common air to the same degree that inflammable air does, it must part with a quantity of phlogiston, equal to the weight of a volume of inflammable air, similar to that of nitrous air. But 100 cubic inches of inflammable air weigh three grains and a half; therefore 100 cubic inches of nitrous air part with 3.5 grains of phlogiston, when they communicate their phlogiston to as much common air as will take it up. In this process, however, the nitrous air does not part with the whole of the phlogiston it contains, as appears by the red colour it constantly assumes when mixed with common or dephlogisticated air; which colour belongs to the nitrous acid, combined with the remainder of its phlogiston, whence the acid produced is always volatile.

"One measure of the purest dephlogisticated air and two of nitrous air occupy but $\frac{3}{100}$ of one measure, as Dr Priestley has observed. Suppose one measure to contain 100 cubic inches, then the whole, very nearly, of the nitrous air will disappear (its acid uniting to the water over which the mixture is made), and 97 cubic inches of the dephlogisticated air, which is converted into fixed air by its union with the phlogiston of the nitrous air; therefore 97 cubic inches of dephlogisticated air take up all the phlogiston which 200 cubic inches of nitrous air will part with; and this we have found to be seven grains: therefore a weight of fixed air equal to that of 97 cubic inches of dephlogisticated air, and 7 of phlogiston, will contain seven grains of the latter. Now, 97 cubic inches of dephlogisticated air weigh 40.74 grains; to which adding 7, we have the whole weight of the fixed air,=47.74 grains,=83.755 cubic inches; and consequently 100 cubic inches of fixed air contain 8.357 grains of phlogiston, the remainder being dephlogisticated air. An hundred grains of fixed air, therefore, contain 14.661 of phlogiston, and 85.339 of elementary or dephlogisticated air. Hence also 100 cubic inches of dephlogisticated air are converted into fixed air by 7.2165 grains of phlogiston, and will be then reduced to the bulk of 86.34 cubic inches.

506
In vitriolic acid air.

To find the quantity of phlogiston in vitriolic acid air, our author pursued the following method.

1. He found the quantity of nitrous air afforded by a given weight of copper, when dissolved in the dephlogisticated nitrous acid, and by that means how much phlogiston it parts with.

2. He found the quantity of copper which a given quantity of the dephlogisticated vitriolic acid could dissolve; and observed, that it could not entirely saturate itself with copper without dephlogisticating a further quantity which it does not dissolve.

3. He found how much it dephlogisticates what it thoroughly dissolves, and how much it dephlogisticates what it barely calcines.

4. How much inflammable air a given quantity of copper affords when dissolved in the vitriolic acid to the greatest advantage.

5. He deducts from the whole quantity of phlogiston expelled by the vitriolic acid the quantity of it contained in the inflammable air; the remainder shows the quantity of it contained in the vitriolic acid air.

The conclusion deduced from experiments, conducted after this manner is, that 100 cubic inches of vitriolic air contain 6.6 grains of phlogiston, and 71.2 grains of acid; and 100 cubic inches of this air weighing 77.8 grains, 100 of it must contain 8.48 grains phlogiston, and 91.52 of acid.

507
Quantity of phlogiston in Sulphur.

To find the quantity of phlogiston in sulphur, Mr Kirwan proposed to estimate that of the fixed air produced during its combustion. For this purpose he firmly tied and cemented to the open top of a glass bell a large bladder, destined to receive the air expanded by combustion, which generally escapes when this

Quantity of Phlogiston in different Substances.

this precaution is not used. Under this bell, containing about 3000 cubic inches of air, a candle of sulphur, weighing 347 grains, was placed; its wick, which was not consumed, weighing half a grain. It

508 Proper method of burning sulphur.

was supported by a very thin concave plate of tin, to prevent the sulphur from running over during the combustion; and both were supported by an iron wire fixed in a shelf in a tub of water. As soon as the sulphur began to burn with a feeble flame, it was covered with the bell, the air being squeezed out of the bladder. The inside of the bell was soon filled with white fumes, so that the flame could not be seen; but in about an hour after all the fumes were thoroughly subsided, and the glass become cold, as much water entered the bell as was equal to 87.2 cubic inches; which space our author concludes to have been occupied by fixed air, and which must have contained 7.287 grains of phlogiston. The candle of sulphur being weighed was found to have lost 20.75 grains; therefore 20.75 grains of sulphur contain 7.287 of phlogiston, besides the quantity of phlogiston which remained in the vitriolic air. This air must have amounted to 20.75—7.287=13.463 grains, which, as already shown, contain 1.41 grains of phlogiston. Therefore the whole quantity of phlogiston in 20.75 grains of sulphur is 8.428; of consequence 100 grains of sulphur contain 59.39 of vitriolic acid, and 40.61 of phlogiston.

509 Quantity of phlogiston in marine acid air.

The quantity of phlogiston contained in marine acid air was found by the following method.—Eight grains of copper dissolved in colourless spirit of salt afforded but 4.9 inches of inflammable air; but when the experiment was repeated over mercury, 91.28 cubic inches of air were obtained. Of these only 4.9 cubic inches were inflammable; and consequently the remainder, 86.38 inches, were marine air, weighing 56.49 grains.—Now as spirit of salt certainly does not dephlogisticate copper more than the vitriolic acid does, it follows, that these 4.9 cubic inches of inflammable air, and 86.38 of marine air, do not contain more phlogiston than would be separated from the same quantity of copper by the vitriolic acid; and since 100 grains of copper would yield to the vitriolic acid 4.32 grains of phlogiston, 8.5 grains of copper would yield 0.367 grains of phlogiston. This therefore is the whole quantity extracted by the marine acid, and contained in 91.28 cubic inches of air; and, deducting from this the quantity of phlogiston contained in 4.9 cubic inches of inflammable air=0.171 grains, the remainder, *viz.* 0.367—0.171=0.196, is all the phlogiston that can be found in 86.38 cubic inches of marine air. Then 100 cubic inches of it contain but 0.227 of a grain of phlogiston, 65.173 grains being acid.—Hence we see why it acts so feebly

510 Why marine acid acts so weakly.

on oils, spirit of wine, *&c.* and why it is not dislodged from any basis by uniting with phlogiston, as the vitriolic and nitrous acids are, its affinity to it being inconsiderable.

§ 4. *Remarks on the Doctrines of the Quantity and Specific Gravity above delivered.*

2d 510 Mr Keir's objections to Kirwan's doctrines.

To this doctrine of the specific gravity and quantity of acid contained in different substances, Mr Keir has made several objections. 1. Mr Kirwan supposes, that marine acid gas is the pure and solid marine acid divested of all water and other matter. Its apparent dryness in this respect, however, is no argument that it really contains no water; for water itself, reduced to a state of vapour, possesses no moistening property.

Remarks on the former Doctrines.

There is great reason to believe that water is a constituent part of some gases, and it is certain that all of them are capable of holding it in solution. As moist materials, therefore, are employed in the preparation of marine acid air, there seems no reason to believe, that in any way in which Mr Kirwan could obtain it, there was reason to suppose it perfectly free of water; in which case the density of the acid would be greater, and its quantity smaller than he supposes.

2. A considerable part of the density of the acid absorbed in the experiment, probably arose from the condensation which always accompanies the union of a concentrated acid with water. Mr Kirwan allows this to be the case with the nitrous and vitriolic acids, but thinks it too inconsiderable to deserve notice in the marine. His reasoning, however, does not appear satisfactory, or his experiments on the subject conclusive. He observes, that the length of time taken up in effecting an union between the marine gas and water, is no argument against their attracting one another strongly when once united; and it is certain that part of this acid gas is very quickly absorbed by water. He also finds fault with his accuracy in calculation; and asserts, that if matters are fairly stated, the real density of the marine acid gas will be considerably less than Mr Kirwan makes it.

3. A great obstacle even to an approximation towards the real density of the acid, arises from the condensation which the water, as well as the acids, must suffer in the process: and in this case, where a general condensation takes place, he asks, "How shall we determine the part of the condensation that belongs to the water, and the part that the acid sustains?" This, with other considerations, makes Mr Keir "doubt of the possibility of solving the question concerning the actual density of pure and solid acids." The investigation of the question, indeed, he does not consider as a matter of great consequence, as every useful application may be obtained, by first investigating the comparative strengths of different portions of the same acid rendered more or less dilute; and then by finding out the strength of the vitriolic, nitrous, and marine acids of known densities, so that they may be compared together. "Homberg (says he) has the merit of making the first essay towards this investigation. Bergman and Wenzal have supplied the defect of Homberg, by taking into consideration the gas united with alkaline substances; and Mr Kirwan, by using determinate quantities of acid liquors of known densities, has considerably improved the method of Bergman: and whoever succeeds these able chemists in this inquiry, may avail himself greatly of their labours, particularly those of Mr Kirwan." He concludes with stating the results of the inquiries made by the chemists abovementioned; on which he makes the following remarks.

3d 510 Great differences in the calculations of different authors.

"The discordancy of these results is very striking, and gives but an humiliating representation of the precision of our present knowledge in chemistry. A great part of the difference arises undoubtedly from the different views in which these authors considered the dryness or purity of the acids. Mr Kirwan, as we have seen, endeavoured to find their density and quantity in

Remarks on the former Doctrines.

a ſtate of perfect dryneſs and purity ; which he ſuppoſed to exiſt in the marine acid gas : with which he compared and inferred the denſities and quantities of the nitrous and vitriolic acids, upon the ſuppoſition that equal quantities of theſe ſeveral acids are ſaturated by a given weight of fixed alkali. Beſides the uncertainty of his principles, from which he deduces the denſity and quantity of the marine acid, his applications from thence to deduce the denſities of the pure nitrous vitriolic acids, being founded on the above ſuppoſition, muſt partake of its defects. The alkali which he happened to fix on as the ſtandard by which he compared the ſtrengths of the different acid liquors, in order to determine the quantity of real acid they contained, and thence to determine their denſity in a ſolid ſtate, was the fixed vegetable. Having found that 100 grains of his real marine acid could ſaturate 215 grains of this alkali, he infers, that the ſame proportion is applicable to the other acids : and accordingly we find that 100 grains of each of the pure and real mineral acids are ſaturated by an equal quantity, *viz.* 215 grains of this alkali. But if we examine the other columns of his table, we ſhall at once ſee, that, in other ſubſtances ſoluble by acids, this equality does not exiſt ; and that every ſuch ſubſtance has a ratio peculiar to itſelf, with reſpect to the proportions of theſe acids neceſſary for its ſaturation. It is evident, therefore, that if Mr Kirwan had fixed on the mineral alkali, the volatile alkali, lime, or any other ſubſtance, as a ſtandard, inſtead of vegetable alkali, his determination of the denſities of the real vitriolic and nitrous acids would have been different ; and as no reaſon can be aſſigned why the vegetable alkali or any other ſubſtance ſhould have the prerogative over the reſt, it is obvious that there can be no ſuch general ſtandard, but that each ſubſtance poſſeſſes ſolely the capacity of determining the proportions of the ſeveral acids neceſſary for its ſaturation.

" The other chemiſts were contented to conſider as the pure and dry acid, that which actually remains in the neutral ſalt, after this has been rendered as dry as poſſible by expoſure to a red heat : and having made their alkalies as dry as they could, they ſuppoſed theſe alkalies to retain the ſame weight in the dried neutral ſalt ; and that the augmentation of the weight gained by the alkali during the formation of the neutral ſalt ſhowed the weight of the dry acid. The uncertainty which affects this method ariſes from the different capacities which different neutral ſalts may poſſeſs of retaining more or leſs water, either as a conſtituent part of the dry ſalt, or merely by the ſtrength of adheſion or affinity. Nevertheleſs, this method being founded ſolely on experiment, without any theoretical inductions, ſeems to furniſh ſome approximation, not perhaps of the abſolute quantity of the acids in their drieſt poſſible ſtate, but of the acids as they actually exiſt in theſe ſalts comparatively with each other. Though the diſagreements between Bergman's and Wenzel's reſults are little in compariſon of the difference between them and Kirwan's, yet as their experiments were made nearly in the ſame manner, and upon the ſame grounds, there ſeems to be ſufficient reaſon to wiſh for a careful repetition of their experiments, or of others with the ſame view, and leſs liable to objections.

" The only difference in the methods employed by theſe two celebrated chemiſts conſiſted in the mode of ſaturation. Bergman probably uſed the common method, but Wenzel employed a very peculiar one. He added to his alkali a greater quantity of acid than was neceſſary for the ſaturation ; and after the alkali was diſſolved, he added a lump of zinc, or of oyſter-ſhell, in order to ſaturate completely the ſuperfluous acid. By obſerving how much of the zinc or oyſter-ſhell the acid diſſolved, and knowing how much of theſe ſubſtances was ſoluble in his acid by former experiments, he inferred the quantity of acid left for the ſaturation of the alkali. Having thus aſcertained the quantity neceſſary to ſaturate the alkali, he mixed together the proper proportions of theſe, and formed his neutral ſalt by evaporating the mixture and drying the ſalt with a red heat. Perhaps the difference in the reſults obtained by theſe two chemiſts might ariſe from their different modes of ſaturation. The common method of aſcertaining the point of ſaturation by means of litmus or other blue vegetable juices, appears ſufficiently exact, is ſimpler, and therefore preferable to that uſed by Wenzel.

" The ſtandard for comparing the ſtrengths of acids, and likewiſe of alkalies with one another, may be either an acid or an alkaline ſubſtance ; and if we had one of each, the proportion of whoſe quantities requiſite for their mutual ſaturation were well aſcertained, the conveniency in making the experiments would be obvious, and the certainty greater. Alkaline, and the earthy ſubſtances that are ſoluble in acids, are ſeldom pure enough for this purpoſe. They generally contain quantities, which are not conſtant, of fixed air, ſiliceous earth, magneſia, neutral ſalts, and inflammable matter, which render any of thoſe that are commonly met with unfit for the purpoſe without a very ſkilful and careful purification. The chemiſts who have made experiments to determine the proportions of acids and alkalies requiſite for each other's ſaturation, have ſcarcely been explicit enough in explaining the means of purifying the alkalies which they employed : for thoſe in commerce are quite uncertain in ſtrength and purity : and as to the general rules for making allowances for any heterogeneous ſubſtances they may contain, they are quite inapplicable to delicate experiments. No other method ſeems proper for aſcertaining the purity of alkalies but that of cryſtallization : of which both the vegetable and mineral alkalies are ſuſceptible, eſpecially the latter, which on account of its being more eaſily reducible into cryſtals, is therefore preferable. Theſe alkaline cryſtals, however, are not fit to be uſed as a ſtandard, becauſe they either are apt to be ſufficiently dried, or, upon expoſure to air, to loſe a part of the water of their cryſtallization, and to fall into powder. Even if they ſhould be taken, as is poſſible with due care, at the exact ſtate of dry but entire cryſtals, another uncertainty ariſes from a property which ſeems to be common to them all, namely, that of retaining a greater or ſmaller quantity of water, according to the degree of heat in which they were cryſtallized ; the colder the weather the greater quantity of water entering into the compoſition of the cryſtals. It ſeems poſſible, however, to make a pretty accurate ſtandard of mineral alkali in the following manner : Let the alkali be purified by repeated ſolution

4th 510 Mr Keir's method of preparing an alkaline ſtandard.

Remarks on the former Doctrines.

tion and cryſtallization, uſing only ſuch as are formed firſt, and rejecting the remaining liquors. Let the pure cryſtals be expoſed to a dry air until they have completely effloreſced or fallen into a dry white powder; which alteration may be facilitated by bruiſing the cryſtals and changing the ſurface of the powder. Let this powder be then expoſed for a certain and determinate time to a conſtant heat, as that of boiling water for 12 hours; letting the ſurface expoſed be in ſome given proportion, ſuppoſe of a ſquare inch to an ounce of the powder of cryſtals, and let it be ſtirred every two hours. When thus dried, let them be put while hot into a bottle, and well ſtopped. This powder I have found to be an uniform and conſtant ſtandard for aſcertaining the ſtrength of acids; and alſo, by compariſon by means of acids, of other alkaline ſubſtances."

With regard to an acid ſtandard, our author recommends oil of vitriol; which, he ſays, as it comes from the hands of the Britiſh manufacturers, is of the ſpecific gravity of about 1.846, but ſoon becomes weaker, unleſs carefully kept from the external air; and in general he rates it at 1.844. One part of this acid mixed with nine of water, is of a very convenient ſtrength for uſe; and as every ten grains of the mixture contain one of the ſtandard acid, the computations are thus rendered eaſy: and by theſe ſtandards, the ſtrength of all acids, alkalies, and ſubſtances ſoluble in acids, may be meaſured and compared together.

5th 510 His method of finding the ſpecific gravity of different liquors.

To determine the ſpecific gravity of liquors with accuracy, our author recommends the method of weighing them in a phial fitted with a glaſs-ſtopper, which can only enter a certain length into the neck. In this way, he obſerves, no other inconvenience can enſue than the ſlight one, that the glaſs-ſtopper, by very frequent uſe, is apt to wear itſelf and the neck of the phial alſo; ſo that after a great number of experiments, it will at laſt diminiſh, in ſome meaſure, the capacity of the phial itſelf. This, however, is but very trifling, and may be corrected at any time. Mr Keir has beſides found, that after ſome hundreds of experiments, the error amounted only to one quarter of a grain in 101 grains.

"The methods hitherto practiſed (ſays he) for aſcertaining the quantities of acids and alkalies contained in neutral ſalts, ſeem to be liable to ſeveral objections beſides thoſe abovementioned, ariſing from the different proportions of water remaining in a neutral ſalt, after expoſure to a red-heat, which heat is alſo very indefinite. In boiling the ſaturated mixture of acid and alkali to dryneſs, and afterwards in expoſing this ſalt to a red-heat, it has been ſuppoſed that nothing but water is expelled; and ſome chemiſts, who have given the reſults, have alſo determined the weight of the alkali which enters into the neutral mixture, by evaporating to dryneſs an equal quantity of the alkaline ſolution which had been employed in the ſaturation, and weighing the dry ſolution, on the ſuppoſition that nothing is expelled but water. It is certain, however, that in the evaporation both of alkalies and neutral ſalts, a conſiderable portion of the ſaline matter is elevated towards the end, when the liquor becomes concentrated and acquires a degree of heat conſiderably above that of boiling water. The following method appears beſt for determining the relative quantities of acid and alkali, or other ſubſtance exiſting in neutral ſalts.

Remarks on the former Doctrines.

"To a given number of grains, ſuppoſe 100 of the ſtandard vitriolic acid, or to a proportionable quantity of any other acid, add as much of the alkali or other ſoluble ſubſtance as is requiſite for the ſaturation, and note the quantity required, which ſuppoſe to be 150 grains. We have thus a ſolution of the neutral ſalt, which is the object of the experiment; the quantities of acid and baſis contained in which are known, and the general proportion of the quantity of the acid to its baſis in the neutral ſalt determined, *viz.* as 100 to 150. The next thing to be diſcovered is the weight of the dry neutral ſalt contained in this ſolution, in order to know the proportion of the dry neutral ſalt to its acid and baſis. For this purpoſe, let a given quantity of the ſame neutral ſalt, either in the ſtate of cryſtals or dried to any given degree, be diſſolved in water. Let this ſolution be brought to the ſame denſity as the former, by adding water to the heavier of the two: then, by knowing the weight of each ſolution, and the quantity of dry neutral ſalt which was actually diſſolved in one of them, the quantity contained in the other may be deduced; and thence the quantities of ſtandard acid, or of other acid proportioned to it, and of the alkali employed, or other ſoluble ſubſtance contained in a given quantity of the neutral ſalt, are determined; alſo the quantity of water contained in the neutral ſalt, that is greater or leſs than what is contained in the quantity of acid employed, will be known, over and above any water that may have been contained in the alkali or other baſis of the neutral ſalt; the quantity of which water, if any, cannot be determined.

"By this method may be aſcertained the proportion of the acid, of the baſis, and of the neutral ſalt, to each other; not indeed the quantity of acid and of alkali deprived of all water, but the quantity of acid, equal in intenſity of acidity to a known portion of the ſtandard acid; and alſo the quantity of ſuch alkali or other ſoluble ſubſtance as was employed; the relative ſtrength of which is known from its ratio to the ſtandard acid."

6th 510 Objection to Kirwan's calculation of the quantity of phlogiſton in ſulphur.

The tranſlator of Wiegleb's Syſtem of Chemiſtry totally diſagrees with Mr Kirwan's calculation of the quantity of phlogiſton contained in ſulphur; but as his objection ſeems to ariſe rather from an inclination to the antiphlogiſtic doctrine that a real diſcuſſion of the ſubject, this can have but little weight. It is poſſible indeed that Mr Kirwan may have over-rated the quantity of phlogiſton this ſubſtance contains, which is indeed larger than that allowed by other chemiſts. "Brandt (ſays the tranſlator), who has been moſt generally followed, reckons it only at $\frac{1}{8}$; and it has always appeared to me, that the weight of phlogiſton in ſulphur is almoſt infinitely ſmall." His objection proceeds on a maxim which he thinks he has demonſtrated, *viz.* that ſulphur is compoſed, not of the vitriolic acid and phlogiſton, but of the *baſe* of vitriolic acid and phlogiſton. No experiments hitherto made, however, have been able to ſhow this baſe diſtinct from the acid; nor have we any reaſon to ſuppoſe that the increaſe of weight in the vitriolic acid above the ſulphur from

Earths. from which it is produced, arises from any thing besides the accession of mere water, which the air parts with during the combustion. Hence, if the sulphur is burnt in a very moist air, the quantity of acid obtained will be four or five times the weight of the sulphur.

SECT. IV. *Earths.*

THESE are divided into five classes: 1. Absorbent, alkaline, or calcareous earths: 2. Argillaceous earths or clay: 3. The flinty: 4. The fusible earths: and, 5. The talks.

1. The first class comprehends all those that are capable of being converted into lime. They are found of various degrees of hardness; but none of them are capable of totally resisting the edge of a knife, or striking fire with steel. They are found to consist of a very friable earth, joined with a large quantity of air and some water. They effervesce with an acid when poured on them; by which they are distinguished from all other kinds of earth, except the argillaceous. When calcined by a strong fire, they part with the water and air which they contained, and then acquire a great degree of causticity, lose their power of effervescing with acids, and become what is called

511 Quicklime. *quicklime.* They are soluble in acids, but not equally so in all. The vitriolic and tartareous acids form compounds with them very difficultly soluble; the *selenites,* formed by the vitriolic acid and calcareous earth, requiring, according to Mr Beaumé, an ounce of water to dissolve a single grain of it. The solubility of the tartareous selenite hath not yet been determined.—With the other mineral acids, the calcareous earths become easily soluble; and by proper management form concretes which appear luminous in the dark, and are called *phosphori.*

512 Argillaceous. 2. The argillaceous earths differ from the calcareous, in not being convertible into quicklime. When mixed into a paste with water, and exposed to the fire, they shrink remarkably, crack in many places, and become excessively hard. By being gently dried in the open air before they are turned, they do not crack, and thus may be formed into vessels of any shape. Of this kind of earth are formed all the brown sort of earthen ware. The purest kind of argillaceous earth naturally found, is that whereof tobacco-pipes are made.

All the argillaceous earths are soluble in acids. With the vitriolic they dissolve into a gelatinous tough liquor very difficultly crystallizable; but which, on the addition of some fixed or volatile alkali, may be shot into crystals of the salt called *alum.* With the other acids they form astringent salts of a similar nature.

The attraction between the argillaceous earths and acids is very weak, yielding not only to alkaline salts both fixed and volatile, but even to some metals, particularly iron; but these earths have as yet been but little the subject of chemical examination in this way. They have a remarkable property of absorbing the colouring matter of cochineal, Brasil-wood, *&c.* as have also the calces of some metals.

Both the calcareous and argillaceous, and indeed all earths when pure, resist the utmost violence of fire; but when mixed together will readily melt, especially if in contact with the burning fuel. Dr Lewis having made covers to some crucibles of clay and chalk mixed together, found that they melted into a yellow glass, before the mixtures in the crucibles were fused in the least. But though they melted thus readily when in contact with the fuel, it was with great difficulty he could bring them to a transparent glass when put into a crucible.

The other species of earths, *viz.* the flinty, fusible, and talky, being no other way the subjects of chemistry than as they are subservient to the making of glass, all that can be said of them will most properly come under that article. For their different species, see MINERALOGY. 513 Anomalous earths.

Besides the abovementioned species of earths, there are others which may be called *anomalous,* as having some resemblance of the calcareous and argillaceous, and yet being essentially different from them. These are the white earth called *magnesia alba,* the earth of burnt vegetables, and that produced from burning animal substances. 514 Magnesia.

Magnesia alba was at first prepared from the thick liquor remaining after the crystallization of nitre; and is now found to be contained in the liquor called *bittern,* which is left after the separation of common salt from sea-water. In the former case it was united with the nitrous, in the latter with the vitriolic, acid. It is also found naturally in the soft kind of stone called *steatites* or "soap-stone;" and in the concrete used for taking spots out of cloaths, called *French chalk.* It differs from the calcareous earths, in not acquiring any causticity when deprived of its air, of which it contains so large a quantity as to lose two-thirds of its weight when calcined. From the argillaceous it differs in not burning hard when mixed with water, nor forming a tough ductile paste. It is easily soluble in all the acids, even the vitriolic; with which it forms the bitter purging salt commonly called *Epsom salt,* from its being first discovered in the waters of Epsom. With all the other acids it likewise forms purgative compounds, which are either very difficultly or not at all crystallizable.—Like other pure earths, it cannot be melted by itself; but, on proper additions, runs into a beautiful green glass. 515 Vegetable and animal earths.

The earth of burnt vegetables is thought by Dr Lewis to be the same with magnesia alba; but on trying the common wood ashes, they were found to be very different. This kind of earth is fusible, by reason of the alkaline salts contained in it. Animal earth is both very difficult of solution in acids, and impossible to be melted in the strongest fire. It dissolves, however, in acid liquors, though slowly; but the nature of the compounds formed by such an union are as yet unknown. The softer parts of animals, such as blood, flesh, *&c.* are said to yield a more soluble earth than the others. Animal earth has lately been supposed to be compounded of calcareous earth and phosphoric acid; but this opinion is shown to be erroneous under the article BONES. The phosphoric acid produced from these, is with reason supposed to be only the vitriolic acid changed.

SECT. V. *Inflammable Substances.*

THESE comprehend all vegetable, animal, and some mineral substances. They are distinguished from all others, 516 Phenomena on burning.

Inflammable Subſtances. others, by emitting a groſs thick ſmoke and flame, when a certain degree of heat is applied. To this, however, ſpirit of wine and all preparations from it are exceptions. They burn without the leaſt ſmoke; and if a glaſs bell is held over the burning ſpirit, no ſoot is formed, only a quantity of water is found condenſed on its ſides. Even the groſſer oils, if ſlowly burnt with a very ſmall flame, will yield no ſoot; and an exceeding great quantity of water, fully equal in weight and bulk to the oil employed, may be obtained from them. We can ſcarcely, however, credit, that ſo great a quantity of water comes from the oil; as this would be a real tranſmutation; and we know that, beſides water, the oils contain alſo ſome quantity of fixed air, as well as earth. It is probable, therefore, that, as it is impoſſible to ſuſtain flame without a decompoſition of that part of the air which ruſhes in to ſupport it, part of the water in this caſe comes from the air, which always contains moiſture in abundance.

Inflammable matters, on being burnt, generally leave behind a ſmall quantity of earthy matter called *aſhes*; but to this, ſpirit of wine, camphor, the more volatile oils, and the mineral oil called *naptha*, are exceptions.

517
On diſtillation. Vegetable ſubſtances, when diſtilled in cloſe veſſels, give out a quantity of air, ſome acid, and an empyreumatic oil, leaving behind a black ſpongy maſs called *charcoal*. To this too there are a few exceptions, *viz.* ſpirit of wine and the preparations from it, camphor, and perhaps ſome of the more volatile oils, or naphtha. Animal ſubſtances yield only a very fetid empyreumatic oil, and volatile alkali.

518
Treated with different acids. In general, all inflammable matters are acted upon with ſome violence by the vitriolic and nitrous acids, excepting only camphor and naphtha. With the vitriolic acid, when in a liquid ſtate, they render it volatile and ſulphureous; if in a dry ſtate, they form actual ſulphur. With the nitrous, they firſt impart a high colour and great degree of volatility to the acid, then a violent flame enſues, if the matter is attempted to be dried. With ſpirit of wine the effects are conſiderably different; and very volatile compounds are formed, which are called *ether*, on account of their exceeding great diſpoſition to riſe in vapour. Similar compounds are likewiſe produced, but with more difficulty, from the marine acid and concentrated vinegar. The ſal ſedativus of borax mixes with ſpirit of wine, and cauſes it burn with a green flame; but does not ſeem to produce any other change upon it. How the acid of phoſphorus and of ants act upon ſpirit of wine, is not exactly known; but that of tartar by digeſtion with it, is converted into the acetous acid. With any other inflammable matter, the phoſphorine acid reproduces phoſphorus.

519
Singular productions. There are two ſingularities obſerved among the inflammable ſubſtances. One is that bituminous matter called *amber*, which yields a volatile ſalt of an acid nature on diſtillation: When combined with alkalies, this acid is found to yield compounds ſimilar to thoſe made with the acetous acid and alkali. The other is, that gum called *benzoin*, which is uſed as a perfume, and yields by ſublimation a kind of volatile ſalt in fine ſhining cryſtals like ſmall needles, and of a moſt grateful odour. Theſe diſſolve very readily in ſpirit of wine; but not at all in water, unleſs it is made very hot: ſo that they ſeem to contain more oily than ſaline matter. Neither the nature of theſe flowers, however, nor that of the ſalt of amber, is fully known.

Sect. VI. *Metalline Subſtances.*

Metalline Subſtances.

These are diſtinguiſhed from all other bodies by their great ſpecific gravity, exceeding that of the moſt denſe and compact ſtones. The heavieſt of the latter do not exceed the ſpecific gravity of water in a greater proportion than that of 4 to 1; but tin, the lighteſt of all the metals, exceeds the ſpecific gravity of water in the proportion of 7 to 1. They are alſo the moſt opaque of all known bodies, and reflect the rays of light moſt powerfully.

520
Metalline Subſtances. Metallic bodies poſſeſs the quality of diſſolving in and uniting with acid ſalts, in common with earths and alkalies; but, in general, their union is leſs perfect, and they are more eaſily ſeparable. They effervesce with acids, as well as calcareous earths and alkalies; but their effervescence is attended with very different appearances. In the effervescence of acids with alkalies, or with calcareous earths, there is a diſcharge of the fluid called *fixed air*, which is ſo far from being inflammable, that it will immediately extinguiſh a candle or other ſmall flame immerſed in it. The mixture alſo is notably diminiſhed in weight. When a metallic ſubſtance is diſſolved in an acid, the weight of the mixture is never very much diminiſhed, and ſometimes it is increaſed. Thus, an ounce of quickſilver being ſlowly dropped into as much aquafortis as was ſufficient to diſſolve it, and the ſolution managed ſo as to take up almoſt a whole day, the whole was found to have gained ſeven grains. There is alſo a remarkable difference between the nature of the vapour diſcharged from metals and that from alkalies; the former, in moſt caſes, taking fire and exploding with violence; the latter, as already obſerved, extinguiſhing flame.

521
Their compoſition. The metallic ſubſtances, at leaſt ſuch as we are able to decompound, are all compoſed of a certain kind of earth, and the inflammable principle called *phlogiſton*. The earthy part by itſelf, in whatever way it is procured goes by the name of *calx*. The other principle has already been proved to be the ſame with charcoal. When theſe two principles are ſeparated from one another, the metal is then ſaid to be *calcined*.

522
Calcination and revivification. The calx being mixed with any inflammable ſubſtance, ſuch as powdered charcoal, and urged with a ſtrong fire melts into metal again; and it is then ſaid to be *reduced*, or revivified: and this takes place whether the metal has been reduced to a calx by diſſolution in an acid or by being expoſed to a violent fire. If, however, the calcination by fire has been very violent and long continued, the calx will not then ſo readily unite with the phlogiſton of the charcoal, and the reduction will be performed with more difficulty. Whether, by this means, *viz.* a long continued and violent calcination, metallic earths might entirely loſe their property of combining with phlogiſton, and be changed into thoſe of another kind, deſerves well to be inquired into.

523
Calcination and increaſe of weight by acids. When a metallic ſubſtance is diſſolved in any kind of acid, and an alkali or calcareous earth not deprived of its fixed air is added, the alkali will immediately be attracted by the acid, at the ſame time that the fixed

ed air contained in the alkali is diſengaged, and the calx of the metal, having now no acid to keep it diſſolved, immediately joins with the fixed air of the alkali, and falls to the bottom. Something ſimilar to this happens when metals are calcined by fire. In this caſe there is a continual decompoſition of the air which enters the fire; and the fixed air contained in it, being, by this decompoſition, ſet looſe, combines with the calx; whence, in both caſes, there is a conſiderable increaſe of weight. If the air is excluded from a metal, it cannot be calcined even by the moſt violent fire.

524
Reaſon of the increaſe of weights in metalline calces.

When a metal is precipitated by a mild alkali, or by an uncalcined calcareous earth, the reaſon of the increaſe of weight is very evident; namely, the adheſion of the fixed air to the metalline calx: but, though it is not ſo much increaſed when precipitated by cauſtic alkali, or by quicklime, there is nevertheleſs a very evident increaſe, which is not ſo eaſily accounted for. M. Lavoiſier has mentioned ſome experiments made on mercury and iron diſſolved in aquafortis, which deſerve to be taken notice of, as in a great meaſure accounting for the phenomenon already mentioned of the ſolution of metalline ſubſtances gaining an addition of weight; and likewiſe ſhow the proportion of increaſe of weight with the mild, or calcined calcareous earth.

525
M. Lavoiſier's experiments.

"Exactly 12 ounces of quickſilver (ſays he) were put into a matraſs, and 12 ounces of ſpirit of nitre poured on it. Immediately a ſpontaneous effervescence enſued, attended with heat. The red vapours of the nitrous acid aroſe from the mixture, and the liquor aſſumed a greeniſh colour. I did not wait till the ſolution was entirely accompliſhed before I weighed it; it had loſt one drachm 18 grains. Three hours after, the mercury was nearly all diſſolved: but having again weighed the ſolution, I was much aſtoniſhed to perceive that it had increaſed inſtead of being diminiſhed in weight; and that the loſs, which was one drachm 18 grains at firſt, was now only 54 grains. The next day the ſolution of the mercury was entirely finiſhed, and the loſs of weight reduced to 18 grains; ſo that in 12 hours the ſolution, though confined in a narrow necked matraſs, had acquired an augmentation in weight of one drachm. I added ſome diſtilled water to my ſolution, to prevent it from cryſtallizing; the total weight of it was then found to be 48 ounces 1 drachm and 18 grains.

"I weighed ſeparately, in two veſſels, 8 ounces 15 grains of the above ſolution, each of which portions, according to the preceding experiment, ought to contain 2 ounces of nitrous acid and 2 ounces of quickſilver. On the other ſide I prepared 6 drachms 36 grains of chalk, and 4 drachms 36 grains of lime; theſe proportions having been found by former experiments juſt neceſſary to ſaturate two ounces of nitrous acid. I put the chalk in the one veſſel, and the lime in the other.

"An effervеſcence attended the precipitation by chalk, but without heat; the mercury precipitated in a light yellow powder, at the ſame time the chalk was diſſolved in the nitrous acid. The precipitation by the lime was effected without efferveſcence, but with heat; the mercury was precipitated in a browniſh powder. When the precipitates were well ſubſided, I decanted off the liquors from them, and carefully edulcorated them. After which, I cauſed them to be dried in a heat nearly equal to that in which mercury boils.

"The precipitate by the chalk weighed 2 ounces 2 drachms 45 grains; that by the lime weighed 2 ounces 1 drachm 45 grains.

"Sixteen ounces of the nitrous acid, the ſame as employed in the former experiments, were placed in a matraſs, and ſome iron filings gradually added. The efferveſcence was briſk, attended with great heat, red vapours, and a very rapid diſcharge of elaſtic fluid: the quantity of iron neceſſary to attain the point of ſaturation was 2 ounces 4 drachms; after which, the loſs of weight was found to be 4 drachms 19 grains. As the ſolution was turbid, I added as much diſtilled water as made the whole weight of the ſolution to be exactly 6 pounds.

"I took two portions, each weighing 12 ounces of the above ſolution, and containing 2 ounces of nitrous acid, and 2 drachms 36 grains of iron filings. I placed them in two ſeparate veſſels. To one were added 6 drachms 36 grains of chalk; and to the other 4 drachms 36 grains of ſlacked lime, being the quantities neceſſary to ſaturate the acid.

"The precipitation was effected by the chalk with efferveſcence and tumefaction, that by the lime without either efferveſcence or heat. Each precipitate was a yellow brown ruſt of iron. They were waſhed in ſeveral parcels of diſtilled water, and then dried in an heat ſomewhat ſuperior to that uſed in the laſt experiment.

"The precipitate by the chalk, when dried, was a greyiſh ruſt of iron, inclining even to white by veins. It weighed 6 drachms 35 grains. That by the lime was rather yellower, and weighed 4 drachms 69 grains.

526
Conſequences from his experiments;

"The reſult of theſe experiments (ſays M. Lavoiſier) are, 1. That iron and mercury diſſolved in the nitrous acid acquire a remarkable increaſe of weight, whether they be precipitated by chalk or by lime. 2. That this increaſe is greater in reſpect to iron than mercury. 3. That one reaſon for thinking that the elaſtic fluid contributes to this augmentation is, that it is conſtantly greater when an earth is employed ſaturated with elaſtic fluid, ſuch as chalk, than when an earth is uſed which has been deprived of it, as lime. 4. That it is probable that the increaſe of weight which is experienced in the precipitation of lime, although not ſo great as that by chalk, proceeds in part from a portion of the elaſtic fluid which remains united to the lime, and which could not be ſeparated by the calcination."

527
Not well founded.

But though we are naturally enough inclined to think that the increaſe of weight in the precipitates formed by lime proceeded from ſome quantity of elaſtic fluid or fixed air which remained combined with the lime, it is by far too great to be accounted for in this way, even according to the experiments mentioned by M. Lavoiſier himſelf, and which, from the manner in which they are told, appear to have been performed with the greateſt accuracy. He found, that 1 ounce 5 drachms and 36 grains of ſlaked lime contained 3 drachms and 3 quarters of a grain of water,

 and

and only 16 grains and an half of elaſtic fluid were ſeparable from it. In the experiments above related, where only 4 drachms and 36 grains were employed, the quantity of elaſtic fluid could not exceed 6 or 8 grains. Yet the calx was increaſed in mercury by no leſs than 105 grains, and in iron by 203 grains; a quantity quite unaccountable from the elaſtic fluid or fixed air which we can ſuppoſe to be contained in the lime made uſe of. It is much more probable, that the increaſed weight of metallic precipitates, formed by lime, ariſes from an adheſion of part of the acid.

Metals are found to be compounded of a kind of earth mixed with the inflammable principle or phlogiſton; and by a diſſipation of the latter, all metallic bodies, gold, ſilver, and platina excepted, are capable

530 **What metals are calcinable, & with what degrees of heat.**

of being reduced to a calx, but very different degrees of heat are required for calcining them. Lead and tin begin to calcine as ſoon as they are melted, long before they are made red-hot. The ſame happens to the ſemimetals biſmuth and zinc; the latter indeed being combuſtible, cannot bear a greater heat in open veſſels than that which is barely ſufficient to melt it. Iron and copper require a red heat to calcine them; though the former may be made partly to calcine by being frequently wetted in a degree of heat conſiderably below that which is ſufficient to make it red.

541 **Ruſting of metals**

Moſt metals undergo a kind of ſpontaneous calcination in the open air, which is called their *ruſting*; and which has given occaſion to various conjectures. But M. Lavoiſier has ſhown, that this ariſes from the fixable part of the atmoſphere attaching itſelf to their earthy part, and diſcharging the phlogiſton. According to him, no metallic body can ruſt but where there is an abſorption of air; and conſequently metals can be but imperfectly ruſted when kept under a receiver.

542 **Fuſibility of metallic compounds.**

If two metals are mixed together, the compound generally turns out more fuſible than either of them was before the mixture. There are indeed great differences in the degrees of heat requiſite to melt them. Thus, lead and tin melt below that degree of heat which is required to make quickſilver or linſeed-oil boil. Silver requires a full red heat, gold a low white heat, copper a full white, and iron an extreme white heat, to make it melt. The ſemimetal

543 **Great fuſibility of compounds of tin and biſmuth.**

called biſmuth melts at about 460° of Fahrenheit's thermometer, and tin at about 422°. When mixed in equal quantities, the compound melted at 283°. When the tin was double the biſmuth, it required 334° to melt it; with eight times more tin than biſmuth, it did not melt under 392°. If to this compound lead is added, which by itſelf melts in about 540°, the fuſibility is ſurpriſingly increaſed. Mr Homberg propoſed for an anatomical injection a compound of lead, tin, and biſmuth, in equal parts; which he tells us keeps in fuſion with a heat ſo moderate that it will

544 **One fuſible by the heat of boiling water.**

not ſinge paper. Sir Iſaac Newton contrived a mixture of the abovementioned metallic ſubſtances, in ſuch proportions that it melted and kept fluid in a heat ſtill ſmaller, not much exceeding that of boiling water. A compound of two parts of lead, three parts of tin, and five of biſmuth, did but juſt ſtiffen at that very heat, and ſo would have melted with very little more; and when the lead, tin, and biſmuth, were to one another in the proportions of 1, 4, and 5, the compound melted in 246°. We have ſeen, however, a piece of metal compounded of theſe three, the proportions unknown, which melted, and even underwent a ſlight degree of calcination, in boiling water, and barely ſtiffened in a degree of heat ſo gentle that the hand could almoſt bear it.

545 **Solubility of metals increaſed by calcination.**

A ſlight degree of calcination ſeems to give the acids a greater power over metallic ſubſtances; a greater makes them leſs ſoluble; and if long and violently calcined, they are not acted upon by acids at all. Of all the acids, the marine has the greateſt attraction for metallic calces, and volitalizes almoſt every one of them.

546 **Effects of ſulphur on metals.**

Sulphur readily unites with moſt metals, deſtroys their malleability, and even entirely diſſolves them. On gold and platina, however, it has no effect, till united with a fixed alkaline ſalt, when it forms the compound called *hepar ſulphuris;* which is a very powerful ſolvent, and will make even gold and platina themſelves ſoluble in water, ſo as to paſs the filter. This preparation is thought to be the means by which Moſes diſſolved and gave the Iſraelites to drink the golden calf which they had idolatrouſly ſet up.

When a metal is diſſolved in an acid, it may be precipitated, not only by means of calcareous earth and alkalies, but alſo by ſome other metals; for acids do not attract all metals with equal ſtrength; and it is remarkable, that when a metal is precipitated by another, the precipitate is not found in a calcined ſtate, but in a metallic one. The reaſon of this is, that the precipitating metal attracts the phlogiſton which is expelled from that which is diſſolving, and immediately unites with it, ſo as to appear in its proper form. The various degrees of attraction which acids have for the different metals is not as yet fully determined. The beſt authenticated are mentioned in the Table of Affinities or elective attractions (Sect. IX.)

547 **Diviſion into metals and ſemimetals.**

Metalline ſubſtances are divided into metals and ſemimetals. The metals which are diſtinguiſhed from the ſemimetallic ſubſtances by their malleability or ſtretching under the hammer, are in number ſeven; gold, ſilver, copper, iron, lead, tin, and platina. To theſe is added quickſilver; which Mr Brown's experiments have ſhown to be a real malleable metal, as well as others, but requiring ſo little heat to keep it in fuſion, that it is always found in a liquid ſtate. The ſemimetals are biſmuth or tin-glaſs, zinc, regulus of

548 **Properties of arſenic.**

antimony, and cobalt, nickel, and arſenic. This laſt ſubſtance is now diſcovered to be compounded of an acid of a peculiar kind and phlogiſton; and as the quantity of the latter is great or ſmall, the arſenic aſſumes either a metallic or ſaline form. It likewiſe unites with ſulphur, with which it forms a compound of a red or yellow colour, according as more or leſs ſulphur is uſed. This compound is eaſily fuſible; though the arſenic, by itſelf, is ſo volatile as to go all off in vapour rather than melt. In common with the ſalts, it poſſeſſes the properties of diſſolving in water, and uniting itſelf to alkalies. Water will diſſolve about $\frac{1}{80}$ of its weight of pure arſenic; but if arſenic is boiled in a ſtrong alkaline lixivium, a much greater proportion will be diſſolved. Indeed ſtrong alkaline lixivia will diſſolve

CHEMISTRY

Chemical Characters or Symbols

△ Fire	Regulus of Antimony	c. Caustic vol. Alkali	A Powder
△ Air	Arsenic	Potash	Ashes
▽ Water	Regulus of Arsenic	Acids	B. A Bath
▽ Earth	K; Cobalt	Vinegar	B.M; M.B; Water bath
f. △ Fixable Air	N. Nickel	Vitriolic Acid	A.B. Sand bath
m. △ Mephitic Air	S.M. Metallic Substances	Nitrous Acid	V.B. Vapor bath
Clay	C. Calx	Marine Acid	An Hour
Gypsum	Orpiment	Æ; Aquafortis	A Day
c. Calcareous Earth	Cinnabar	Æ; Aqua Regia	A Night
C V; Quicklime	L.C. Lapis Calaminaris	Vol. Sulphureous Acid	A Month
Vitrifiable or Siliceous Earths	Tutty	Phosphoric Acid	aaa; Amalgam
Fluors or Fusible Earths	Vitriol	V Wine	To Distill
X Talk	Sea Salt	Spirit of Wine	To Sublime
M.▽ Magnesia	Sal Gem	R Rectified	To Precipitate
A▽; Earth of Alum	Nitre	Æ Ether	A Retort
∴ Sand	Borax	Lime Water	XX. An Alembic
☉ Gold	S S Sedative Salt	Urine	A Crucible
☽; Silver	Sal Ammoniac	Oil	S.S.S. Stratum Super Stratum
♀ Copper	Allum	△; E. Essential Oil	C.C. Cornu Cervi Hartshorn
♃ Tin	Tartar	▽ Fixed Oil	A Bottle
♄ Lead	Alkali	Sulphur	gr.i. A Grain
☿ Mercury	Fixed Alkali	Hepar of Sulphur	℈i. A Scruple
♂ Iron	Volatile Alkali	Phosphorus	ʒi. A Dram
Zinc	m. Mild fixed Alkali	Phlogiston	℥i. An Ounce
B; W°. Bismuth	c. Caustic fixed Alkali	Soap	℔i A Pound
Antimony	m. Mild vol. Alkali	Verdigrise	dwt.i A Penny weight
		Glass	
		Caput Mortuum	

Scot Philad.

Waters, &c. solve a part of almost every metalline substance, except gold, silver, and platina; but, excepting copper, which may be formed into crystals by means of the volatile alkali, none of them will assume a crystalline form when united with alkalies. Arsenic, on the contrary, unites very readily with fixed alkalies, and shoots with them into a neutral salt. If it is mixed with nitre, it unites itself to the alkaline basis of that salt, and expels the acid in very volatile fumes, which are difficultly condensed into a blue liquor. The reason of this is the great attraction between the nitrous acid and phlogiston, which are always disposed to unite when a proper degree of heat is applied. Was the phlogiston contained in large quantity in the arsenic, and the heat sufficiently great, a violent deflagration would ensue; but as the acid of arsenic attracts the alkaline part of the nitre, at the same time that the nitrous acid attracts the phlogiston, a double decomposition ensues, in a less degree of heat than would otherwise be necessary; and the nitrous acid arises in a very volatile state, as it always is when combined with phlogiston, which is the occasion of the blueness in aquafortis so produced. The arsenic is also decomposed by being deprived of its proper quantity of phlogiston; in consequence of which its acid attaches itself to the fixed alkali of the nitre, and forms a neutral arsenical salt. For the extraction of metallic substances from their ores, and the various methods of refining them, see METALLURGY.

SECT. VII. *Waters.*

THE pure element of water, like that of fire, is so much an *agent* in most chemical operations, as to be itself very little the *object* of practical chemistry. Some late experiments, however, have shown that this fluid really consists, in part at least, of phlogiston, and an invisible substance which forms the basis of pure air: and consequently water is generated in the deflagration of dephlogisticated air; but as the basis of the former cannot be perceived by itself, we can as yet say nothing

549 Water, how far an object of chemistry.

about it. Waters, therefore, can only be the objects of chemistry, in consequence of the impurities they contain: and as these impurities are most commonly of the saline kind, it is impossible that any general theory can be given of waters, distinct from that of the salts contained in them; which all depend on the general properties belonging to salts, and which we have already mentioned. Any thing that can be said with regard to waters, then, must be postponed to the particular consideration of the properties of each of the saline bodies with which water is capable of being adulterated. We shall therefore refer entirely to the article WATER in the order of the alphabet, for what can be said on this subject.

SECT. VIII. *Animal and Vegetable Substances.*

550 Chemical properties.

THE general chemical properties of these have been already taken notice of under the name of *inflammable substances*. They agree in giving out a very thick fetid oil, when distilled by a strong fire; but in other respects they differ very considerably. Most kinds of vegetables give out an acid along with the oil; but all animal substances (ants, and perhaps some other insects, excepted) yield only a volatile alkali. Some kinds of vegetables, indeed, as mustard, afford a volatile alkali on distillation, similar to that from animal substances; but instances of this kind are very rare, as well as of animals affording an acid. Both animal and vegetable substances are susceptible of a kind of fermentation, called *putrefaction*, by which a volatile alkali is produced in great plenty: there is, however, this remarkable difference between them, that many vegetable substances undergo two kinds of fermentation before they arrive at the putrefactive stage. The first is called the *vinous*, when the ardent spirits are produced, which we have already mentioned when speaking of inflammable substances. This is succeeded by the *acetous*, wherein the vegetable acid called *vinegar* is produced in plenty: and lastly, the putrefactive stage succeeds when a volatile alkali is only produced; not the smallest vestige either of ardent spirits or of vinegar remaining. On the other hand, animal substances seem susceptible only of the putrefactive fermentation; no instance having ever occurred where there was the least drop, either of ardent spirit or of vinegar, produced from a putrified animal substance. (See FERMENTATION and PUTREFACTION.)

Chemical Characters.

SECT. IX. *Of the Chemical Characters, and Tables of Elective Attraction.*

551 Invention of marks or characters.

THE numerous *marks* or *characters* by which the ancient chemists used to denote many different substances were invented rather from a superstitious and fantastical principle than from any real necessity; or, perhaps, like the enigmatical language used by the alchemists, they have thereby sought to conceal their mysteries from the vulgar. In contriving these marks, they affected a great deal of ingenuity; intending them as symbols of the qualities possessed by each of the different substances. A circle being supposed the most perfect figure, was therefore used to represent the most perfect metal in nature, that is, *gold*. Silver being likewise a perfect and indestructible metal, is placed next to gold; but, on account of its inferiority, is expressed only by a crescent, as if but half gold. A circle was likewise used to denote salt of any kind, as being something elaborate and perfect. A cross was used to denote acrimony of any kind, and consequently employed for the acrimonious salts of vitriol, alkali, &c. Hence all the inferior metals have the cross some how or other combined with the marks designed to represent them. Thus, the mark for quicksilver denotes, that it hath the splendor of silver, the weight of gold, but its perfection is hindered by an acrimony represented by the cross at bottom, &c. Fire is represented by an equilateral triangle, having one of its angles uppermost. This may be considered as a rude representation of flame, which is always pointed at top. Water, again, is represented by a triangle, with an angle downwards, showing the way in which that element exerts its strength, &c. All these marks, however, as they were of no real use at first, so they are now becoming every day more and more neglected. Such of them, however, as may most readily occur in chemical books are represented and explained on Plate CXXXII.

552 New chemical language.

The French chemists have of late attempted to introduce a kind of new chemical language; and by adopting it themselves, may perhaps make it at last universal,

Elective Attraction.

versal, as it is now impossible to understand their writings without knowing it. See the Table at the end of this article.

553 Of tables of affinities.

Tables of affinities, or *elective attractions*, are but of late invention. They are consequences of an improved state of chemistry, when the different substances were found to act upon one another in most cases according to a fixed and settled rule. The most approved table of this kind for a long time was that composed by Mr Geoffroy. It was, however, found to be very incomplete, not only as to its extent, but likewise as heat and some other circumstances were found to vary the attractions considerably, and sometimes even to reverse them. Other tables have been constructed by Mr Gellert, &c. but none hath yet appeared so complete but that many additions may be made to it. The following is that at present exhibited by Dr Black in his course of chemistry.

1. VITRIOLIC ACID.
Phlogiston
Terra ponderosa
Fixed alkali
Calcareous earth
Zinc
Iron
Tin
Copper
Quickfilver
Silver
Volatile alkali
Magnesia
Earth of alum.

2. NITROUS ACID.
Phlogiston
Fixed alkali
Calcareous earth
Zinc
Iron
Lead
Tin
Copper
Quickfilver
Silver
Volatile alkali.

3. MARINE ACID.
Fixed alkali
Calcareous earth
Zinc
Iron
Lead
Tin
Copper
Regulus of antimony
Quickfilver
Silver
Spirit of wine
Volatile oils
Gold.

4. SULPHUR.
Fixed alkali
Calcareous earth
Iron
Nickel
Copper
Lead
Tin
Silver
Regulus of antimony
Quickfilver
Arsenic.

5. HEPAR SULPHURIS is partially decompounded by
Quickfilver
Solution of fixed alkali
Lime-water
Volatile alkali.

6. FIXED AIR.
Calcareous earth
Fixed alkali
Magnesia
Volatile alkali.

7. ALKALINE SALTS.
Vitriolic acid
Nitrous acid
Marine acid
Acetous acid
Volatile vitriolic acid
Sedative salt
Fixed air
Sulphur
Expressed oils.

8. CALCAREOUS EARTH.
Vitriolic acid
Nitrous acid
Marine acid
Acid of tartar
Acetous acid
Sulphureous acid and sedative salt
Sulphur.

9. METALLIC SUBTSANCES, Lead and Regulus of Antimony excepted.
Marine acid.
Vitriolic acid
Nirtous acid
Sulphur and acetous acid.

10. LEAD.
Vitriolic acid
Marine acid
Nitrous acid
Acetous acid
Expressed oils.

11. REGULUS of ANTIMONY.
Vitriolic acid
Nitrous acid
Marine acid
Acetous acid.

12. ARSENIC.
Zinc
Iron
Copper
Tin
Lead
Silver
Gold.

13. REGULUS of ANTIMONY with Metals.
Iron
Copper
Tin
Lead
Silver
Gold.

14. QUICKSILVER.
Gold
Lead and tin
Copper
Zinc, bismuth, and regulus of antimony.

15. SILVER.
Lead
Copper
Iron.

16. WATER.
Fixed alkali
Spirit of wine
Milk, alkaline salts, and some neutrals.

17. SPIRIT of WINE.
Water
Oils and resins.

In consequence of heat, sedative salt and the other solid acids decompound vitriolated tartar, nitre, an sea-salt.

Double Elective Attractions; which, in some cases, may be considered as exceptions to the foregoing table.

I. Those which happen in mixtures of watery substances.

1.	Acids	Volatile alkali
	Calc. earths, or metallic substances	Fixed air.
2	Vitriolic or marine acids	Mercury, silver, or lead,
	Alkalies or earths	Nitrous or acetous acids.
3	Lead	Vitriol acid
	Nitrous marine, or acetous acids	Alkalies, earths, or M. S.
4.	Silver	Marine acid
	Vitriolic, nitrous, or acetous acids	Alkaline salts, earths, or M. S.
5.	Volatile alkali	Fixed air
	Acids	Fixed alkali.
6.	Nitrous, marine, or acetous acids	Volatile alkali, magnesia, or earth of alum
	Calcareous earths	Vitriolic acid.

II. Those which happen in distillations or sublimations, and require heat.

1.	Vol. alkali	Fixed air
	Acids	Calcareous earths.
2.	Vol. alkali	Nitrous, marine, or acetous acids
	Vitriol. acid	Fixed alkali.
3.	Vol. alkali	Acetous acid
	Nitrous, marine, or vitriolic acids	Fixed alkali, or absorbent earths.

A.

Chemical Operations.

4.	Reg. of antimon. / Sulphur	Marine acid / Quickfilver.

III. Thofe which happen in mixtures by fufion.

1.	Tin / Silver	Iron / Lead.
2	Copper / Gold	Sulphur / Lead.
3.	M. S. / Gold	Sulphur / Reg. of ant.

The firft of thefe tables requires very little explanation. The names printed in fmall capitals, are thofe of the fubftances which have the affinity with or attract thofe below them. Thus, vitriolic acid attracts moft powerfully the phlogifton, or inflammable principle: next, fixed alkali; then, calcareous earth; and fo on, in the order in which they are marked. — The tables of double elective attractions cannot be made quite fo diftinct; though an explanation of one example will make this likewife eafy to be underftood. Thus in Table I. the firft cafe is, "If a combination of acids with calcareous earths or metallic fubftances is mixed with a combination of volatile alkali and fixed air, the acids will unite themfelves to the volatile alkali, and the fixed air to the calcareous earth or metallic fubftance.

Sect. X. *Of the different Operations in Practical Chemiftry, and the proper Inftruments for performing each.*

554 Operations in chemiftry.

The moft remarkable operations in chemiftry, and by which the greateft changes are made upon thofe bodies which are the objects of that fcience, may be comprehended under the following names. 1. Solution. 2. Filtration. 3. Precipitation, or coagulation. 4. Evaporation. 5. Cryftallization. 6. Diftillation. 7. Sublimation. 8. Deflagration. 9. Calcination. 10. Fufion. 11 Maceration, or digeftion. To which we may add, 12. Trituration, or levigation.

555 Chemifts how divided.

Before we proceed to a particular account of each of thefe operations, it is neceffary to take notice, that there are two different things propofed by thofe who enter on the practice of chemiftry. Some have nothing farther in view than the enlargement of their knowledge, or making improvements in arts which are to be practifed by others for their own advantage. Others defign to follow chemiftry as a trade, by which they hope to enrich themfelves, or to get a comfortable livelihood. But the apparatus and utenfils neceffary for performing the very fame operations are exceedingly different when experiments only are to be made, from what they muft be when thefe operations are performed with a view to profit; and fo great is this difference, than thofe who purfue chemiftry with a view to advantage, will always find themfelves very confiderable lofers if they follow the plan of an apparatus or a laboratory defigned only for making experiments. Along with the apparatus, therefore, which is commonly defcribed in chemical books, and proper only for experiments, we fhall alfo give that which is neceffary for preparing great quantities of any chemical article in the way of trade.

556 Glafs veffels, when to be ufed.

In general, thofe who practice chemiftry merely with an experimental view, ought, as much as poffible, to make ufe of glafs veffels, as not being liable to be corroded by the moft powerful folvents; and, by their tranfparency, giving an opportunity of obferving what paffes within them during the operation. But by thofe who practife chemiftry with a different view, thefe veffels ought, with equal care, to be avoided, on account of their expence and brittlenefs. This laft quality, indeed, is poffeffed by glafs in fo eminent a degree, that glafs veffels will fometimes fly to pieces, and that with confiderable violence, when ftanding by themfelves, and nothing touching them. The principle objects which a chemift ought to have in view, in performing his operations, ought to be to fave time and fuel, efpecially the former; and for this purpofe, he would find himfelf a confiderable gainer, though he fhould be at much greater expence in his apparatus than he would otherewife have occafion for.

557 Dr Black's obfervations on chemical veffels.

On the fubject of chemical veffels Dr Black obferves, that "with regard to the material of which thefe are compofed, we are very much at a lofs; and indeed there are no fuch materials in nature as are capable of anfwering the purpofes of chemifts in abfolute perfection.—The qualities are, 1. Tranfparency to allow us to fee the changes going on; 2. The power of refifting the action of acids and corrofive fubftances; 3. That they bear fudden alterations of heat and cold without breaking; 4. That they be ftrong, in order to confine elaftic vapours; and, 5. That they bear very great heat without melting. As thefe qualities, however, are not to be met with united in any one fubftance, the chemifts are obliged to have recourfe to different fubftances which poffefs fome of them differently. Thefe are, *glafs*, *metal*, and *earthen ware*.

558 Good and bad qualities of glafs as a material for chemical veffels.

Glafs is poffeffed of the two firft properties, but has the inconvenience of being apt to crack and fly in pieces, on any fudden tranfition from heat to cold, or from cold to heat. The beft method of remedying this defect, is to have the glafs made very thin, and of a round figure, that it may be all heated as equally as poffible; as it is the unequal application of the heat which caufes it break. Another requifite in the choice of chemical glaffes, is that they be well annealed. If this is not done, the glafs will either immediately fly to pieces, or be liable to break on the fmalleft accident.

559 Extreme fragility of glafs not well annealed.

That fuch glaffes fhould be liable to be broken on every flight occafion, is a phenomenon that has hitherto received no explanation. If you touch them with a diamond, with a piece of flint, glafs, &c. or expofe them to the heat of the fun, they break immediately. Dr Black has had great veffels of glafs, which broke immediately on his throwing a little fand into them to clean them. This manifeftly depends upon the fame principles as the qualities of what are called *glafs tears*.

560 Good and bad qualities of metals as materials for chemical veffels.

Glafs when well annealed is univerfally to be preferred, where great and fudden changes of heat, or much ftrength, are not required. Flint-glafs is the beft; but the coarfer kinds, as bottle-glafs, are very apt to break.

The metals have the third and fourth qualities in perfection, but are deficient in all the reft. The moft troublefome property is, that they are liable to be corroded by acids and other bodies, as is the cafe with iron and copper; though this is in fome

Chemical Operations.

meaſure remedied by tinning; which, though it wants ſome of the qualities from its melting too ſoon, yet reſiſts the action of many acrid ſubſtances without being ſo readily injured by them; but it is not entirely free from this imperfection, and is liable to be ſomewhat corroded and ruſted. In nice operations, therefore, recourſe is had to ſilver and even to gold veſſels.

561 Of earthen ware.

Earthen ware poſſeſſes only the fifth quality in perfection, *viz.* that of bearing a violent heat without fuſion. The baſis of theſe veſſels is clay, which, when good, is very convenient for the formation of veſſels, and it has been uſed from the earlieſt ages of chemiſtry for this purpoſe. The requiſite qualities are, 1. A conſiderable degree of toughneſs when mixed with water. 2. A great degree of hardneſs when burnt in the fire with a violent degree of heat. The beſt kind of clay thus contracts a degree of hardneſs ſcarce inferior to flint, as is the caſe with that of which tobacco-pipes are made; but moſt other kinds, ſuch as that of which bricks are conſtructed, are apt to melt with a ſtrong heat into a ſpongy matter. Clay, however, can ſeldom be uſed alone; for when burnt to extreme hardneſs, the veſſels are very liable to crack. This is remedied by mixing ſand reduced to a particular degree of fineneſs, with the clay of which the veſſels are made. For this purpoſe both the fineſt and the coarſeſt particles of the ſand muſt be thrown away.

562 Black lead a valuable material for ſome purpoſes.

Another ſubſtance known by the name of black lead, uſed in the making of pencils, reſiſts the fire exceedingly. This, however, does not contain an ore of lead, but ſulphur, and ſome mineral ſubſtances; when mixed with clay, however, it makes it reſiſt the fire ſurpriſingly. But there are ſome particular caſes in which neither ſand nor black lead can be uſed as a material; for the ſand is eaſily corroded by acrid matters, and the black lead would produce other inconveniences. Clay is therefore to be taken in its unburnt ſtate, reducing it to a powder like ſand; then burning this powder with a violent heat, ſo as to convert it into ſand. Mixing it then with raw clay, it forms a compoſition which anſwers very well for making chemical veſſels, and may be employed in thoſe particular caſes where ſand would not anſwer. Pott of Berlin has written upon the different kinds of earthen ware proper to be employed in the conſtruction of chemical veſſels. There is a French tranſlation of it in four or five volumes.

563 Porcelain veſſels when to be uſed.

In caſes where the utmoſt compactneſs of texture is required, procelain veſſels are to be choſen; which is compoſed of the fineſt clay, mixed with a ſtony matter, that has the quality of melting in a violent heat, and gives more compactneſs to the clay than it is naturally capable of receiving; but theſe are rather too coſtly for moſt operations. Reaumur has taught a way of converting glaſs into porcelain.

We ſhall now proceed to a particular deſcription of each of the operations abovementioned.

564 Solution.

I. SOLUTION. By this is underſtood the diſſolving a ſolid ſubſtance in a fluid, ſo as that the ſolid ſhall totally diſappear, and become part of a tranſparent liquor. This operation applies particularly to ſalts, earths, and metals: as well as to ſeveral unctuous and inflammable ſubſtances. For performing this operation in a ſmall way, common vials are in many caſes ſufficient. Where

Chemical Operations.

Plate CXXXIV.

the ſolution is attended with effervefence and a diſcharge of vapours, the long-necked glaſſes called *matraſſes*, or *bolt-heads*, (fig. 5.), are neceſſary. Florence flaſks are indeed exceedingly well adapted for this operation, as being of the proper ſhape, and capable of bearing heat ſo well, that they may be filled with any fluid, and ſet on a common fire like a metalline veſſel. Solution is much promoted by agitating the veſſel, and by heat. In ſome caſes, indeed, it will not take place till the mixture becomes very hot; and in ſuch caſes it will be proper to make the fluid boiling hot by itſelf, and then ſlowly to add the ſubſtance to be diſſolved.

When large quantities of ſaline matter are to be diſſolved, metalline veſſels muſt be uſed: but before any are made uſe of for this purpoſe, it will be neceſſary to make an experiment whether the ſalt receives any impregnation from the metal of which the veſſel intended to be made uſe of is formed; and if this is found to be the caſe, it muſt not be uſed. The metals moſt liable to be corroded by ſaline bodies are iron and copper; and indeed, unleſs it be for the ſingle purpoſe of diſſolving fixed alkaline ſalts, iron veſſels ſeem totally unfit for ſaline ſolutions of any kind. Copper veſſels are alſo very liable to be corroded, and to communicate very miſchevous qualities to the liquors which corrode them; for which reaſon, they ought never to be made uſe of for the purpoſes of ſolution. The metal leaſt liable to be corroded, next to gold and ſilver, is lead; and therefore a chemiſt ought rather to provide himſelf with leaden veſſels than thoſe of any other metal. But though lead is not apt to be corroded by many kinds of ſalts, there are ſome which are found to act upon it, and to form therewith a very dangerous poiſon. The vegetable acid of vinegar is particularly apt to receive a dangerous impregnation from this metal; and therefore no ſolution of any ſalt containing this acid ought to be made in leaden veſſels. It appears to be very little affected by the vitriolic or marine acids; and therefore any ſaline ſubſtance containing either of theſe acids may be ſafely enough diſſolved in veſſels made of lead.

In order to ſave time in making ſolutions, the veſſels ought to be as large as poſſible; though even in this there muſt be a certain limit: for two ſmall veſſels filled with water will ſooner acquire the neceſſary degree of heat than one large one; and in proportion as the veſſel is made more capacious, the ſides and bottom muſt be thicker, which conſiderably increaſes the expence. Fifteen or twenty Engliſh gallons is the utmoſt capacity of which they ever will be required; and is rather above what will on moſt occaſions be neceſſary. They ought to be of a conical figure, round at the bottom; and to have a cover of thick plate-iron all around that part which is expoſed to the action of the fire, that the lead may not bend on the application of heat, which it would otherwiſe be very apt to do. When the ſolution is to be made, the leaden veſſel is firſt to be filled up with water ſo far as to have room for the quantity of ſalt intended to be diſſolved: a fire is then to be applied ſo as to make it boil: and then the ſalt is to be added ſlowly, ſo as ſcarcely to hinder the boiling; for if a great quantity was thrown in at once, ſo as to cool the liquor very much, great part of the ſalt would concrete on the bottom, in ſuch

CHEMISTRY. Plate CXXXIII.

Chemical Characters or Symbols.

Acid of Fluor	Amber.	Colouring matter of	Fixed vegetable
Arsenic	Sugar of Milk.	Prussian Blue falsely	Alkali.
Borax	Vinegar.	called an Acid.	Mineral Alkali.
Sugar	Milk.	Phlogisticated vitri-	Ponderous Earth.
Tartar	Ants.	olic Acid the same w.t	Pure Air.
Sorrel	Fat.	Vol. Sulphureous Acid.	Platina.
Lemon	Phosphorus.	Dephlogisticated	Manganese.
Benzoin	Aerial.	Marine Acid.	Metallic calx.

Thackara & Vallance Sculp.t

Chemical Operations

a manner as not only to be very difficultly soluble, but even endanger the melting of the vessel. It is of some consequence also to avoid the hot steam which proceeds from the boiling water, and which issues with great force from a narrow-mouthed vessel, such as we have been describing. That the operator may be out of the reach of this, and likewise dissolve the salt in a regular and gradual manner, without any danger of its concreting on the bottom, it will be proper to have a leaden, or even a wooden, vessel, with a long handle; which is to be filled with the substance to be dissolved, then immersed in the boiling liquor, and shaken about in it, till the salt is made into a kind of thick pap, which will be in no danger of concreting. It will also be proper not to saturate the water perfectly with salt; for it will in that case be impossible to hinder part of it from settling on the bottom, where it soon acquires such a degree of heat as to melt the lead. Before any saline substance is put into water for solution, it ought to be pounded and sifted through a hair sieve.

Where large quantities of metal are to be dissolved in acids, especially the nitrous acid, glass vessels are in a manner indispensable; although the common stoneware bottles, especially those made in Holland, will answer the purpose very well, as not being liable to corrosion, and not so apt to break as the glass vessels are. They may be got of such a size as to hold three or four gallons: but no vessel in which metalline solutions are made ought ever to be above half full.

In solutions of oily and inflammable substances, cast iron vessels are perhaps the most proper of any; though copper ones are generally preferred. The copper is excessively soluble in oil, especially if it is left to cool in such a vessel; but iron is not soluble in any inflammable matter except sulphur. Copper has, however, this advantage over iron, that it is sooner cooled, as the vessels made of copper are thinner than they can be made of cast iron: so that if too great heat is applied to a copper vessel, it may be easily remedied by taking it off the fire; but in a cast iron vessel the heat continues so long as may sometimes produce dangerous consequences, even after the fire is removed.

565 Dr Black's directions for solution.

Dr Black observes, that for the purpose of solution, if no particular nor uncommon consequence follow the application of the two bodies to each other, and if none of them be very volatile, any glass or porcelain vessel that can resist the action of the substances will answer the purpose; but it often happens that they break out into violent ebullition, which produces steam; and here a common vessel is not so proper, as we would wish to have the vapour confined or condensed. We therefore choose a close vessel that will bear the heat suddenly produced by the mixture, or the heat that may be necessary to promote the action of such bodies upon one another. Of this kind is the *phiala chemica*, or matrass, in which the vapours will have time to circulate and to be condensed again, without being allowed to escape. Where the matter is in small quantity, smaller vessels somewhat of the same form are used, as Florentine flasks, which bear sudden changes of heat and cold remarkably well, on account of their thinness. In order to promote the action of bodies, it is sometimes necessary to make the fluids boil; and for this purpose we must have a matrass with a large neck, or apply another vessel to it that will receive these steams, and give them still more room for their condensation, and direct them to fall back again, when condensed, into the matrass. This is called *circulation*. Macquer describes another vessel called the *pelican*, which has been made use of for this purpose; but it is hardly ever employed, on account of its being so troublesome to procure and manage it; and the advantages arising from it may be obtained by a more simple apparatus.

566 Pelican. Fig. 6.

567 Papin's digester. Plate CXXXIII.

To this head we must refer Papin's digester, which is represented Fig. 4. It is generally made of copper, very thick and strong, open at the top, with a lid fitted to it, which applies very exactly. There are usually two projections on the side, designed to make the lid go in a particular manner, but they are unnecessary. There are other two, to which are fitted the two sides of a cross bar B B; in which cross bar there is a strong screw D, by which the lid can be pressed down very strongly. Its use is to force water to bear a stronger heat than it can do under the ordinary pressure of the atmosphere. It is sometimes furnished with an apparatus for letting out the steam, lest it should be in danger of bursting the vessel. A pipe is passed through the lid which is fitted with a valve, on which passes a lever at a very small distance from its centre of motion; and this can be made to press on the valve with different weights, according to the distance of these weights from the centre. In one constructed by Dr Black, there was another pipe below, into which a thermometer could be introduced, in order to measure the degree of heat to which the steam was raised. This machine was pretty much employed some time ago, and its effects were much admired; but we find that most things which can be dissolved in this way, can likewise be dissolved in the ordinary way by boiling water, provided it is continued for a longer time, as animal bones, from which the gelatinous parts are indeed extracted very quickly by this vessel; but the same change is produced by boiling them in water for a long time in the ordinary degree of heat.

568 Filtration.

II. Filtration. This operation is generally the attendant of solution: very few substances, of the saline kind especially, are capable of being dissolved without leaving some impurities, from which they must be freed; and the doing of this, so as to render the solution perfectly transparent, is what is understood by the word *filtration*.

For purposes merely experimental, a glass funnel and piece of paper are generally sufficient. The paper is formed into a conical cap, which being placed in the funnel with its point downwards, the funnel is then placed in the mouth of a vial; and the solution or other liquor to be filtered is poured into the paper cap, through which the liquor passes transparent, leaving its impurities on the paper. For the purpose of filtration, paper has come into such general use, that a particular kind of it is prepared under the name of *filtering paper*. This is of a reddish colour; but Dr Lewis prefers the whitish grey paper which comes from Holland about the pill boxes, as not giving any colour to the solutions which pass through it.

This operation though apparently so simple and easy, is nevertheless attended with very troublesome circumstances, on account of the great time it takes up. Even where very small quantities of liquor are to be filtered,

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merely for experiment's sake, the impurities frequently settle on the paper so soon, and obstruct its pores to such a degree, that the operator is often quite wearied out: often, too, the paper breaks; and thus the whole is spoiled, and the operation must be begun over again.

To avoid these inconveniences, another method of filtration has been proposed; namely, to use a number of cotton threads, the ends of which are to be immersed in the liquor, and the other ends are to hang over the side of the vessel which contains it, and to hang lower than the surface of the liquor. By this means they will act as so many capillary syphons, (see SYPHON); the liquor will arise in them quite pure, and be discharged from their lower extremities into a vessel placed to receive it. That the liquor may flow freely into the cotton, it will be proper to wet the threads before they are used.

In point of efficacy, no doubt, this method excels every other; and where the operator has abundance of time and patience, may be proper for experiments; but, in the way of trade, such a contrivance is evidently useless. For filtering large quantities of liquor, therefore, recourse has been had to large funnels; earthen cullenders, or basons full of holes in the bottom, lined with filtering paper; and to conical bags of flannel or canvas

The inconveniences attending funnels, when used only in the way of experiment, are much greater when they are employed for filtering large quantities of liquor; and therefore they are generally laid aside. The earthen cullenders, too, do not answer any good purpose; nor indeed does filtration through paper in general succeed well. The conical flannel or canvas bags are greatly preferable: but they have this inconvenience, that the pressure of the liquor is directed chiefly against one particular point, or a small part of the bottom, and therefore the impurities are forcibly driven into that place; and thus the operation becomes insufferably tedious.

The best method of obviating the inconveniences of filtration seems to be the following. Let a wooden frame of about three feet square be made, having four holes, one in each corner, about three quarters of an inch in diameter. This frame is to be supported by four feet, the ends of which must project an inch or two through the holes. Thus the whole may be occasionally set up and taken down so as to go into very little compass; for if the feet are properly placed, each with a little projection outwards, there will be no danger of its falling. A square piece of canvas must also be procured, somewhat less than the wooden frame. On each corner of it there must be a very strong loop, which slips on one of the projecting ends of the feet, so that the canvas may hang a little slack in the middle of the frame. The liquor to be filtered is now poured into the canvas, and a vessel placed underneath to receive it. At first it will pass through very foul; but being returned two or three times will become perfectly transparent, and will continue to run with great velocity, if the filter is kept constantly full. A filter of the size just now mentioned will contain ten gallons of liquid; which is a very great advantage, as the heat of such a quantity of liquor is not soon dissipated, and every solution filters much faster when hot than when allowed to cool.

The advantages of a filter of this kind above others arise from the pressure of the liquor being more equally diffused over a large space, by which the impurities are not forced so strongly into the cloth as to stop it up entirely. Yet even here, where large quantities of liquor require filtration, the cloth is apt to be stopped up so as to make the operation not a little tedious and disagreeable. It will be proper therefore to have several cloths, that one may be applied as soon as another is taken off.

To promote the operation of filtration, it is very proper to let the liquors to be filtrated settle for some time; that so their grosser feculencies may fall to the bottom, and thus there will be the fewer to retard the last part of the operation. Sometimes, however, these feculencies refuse to settle till after a very long time; and where this happens to be the case, a little powdered quicklime thrown into the boiling liquor remarkably promotes the separation. This, however, can only be used in certain cases.

569 Schemes for filtering large quantities of water.

In some cases, the discovery of a ready way of filtering a large quantity of liquor would be a matter of great consequence; as where a town is supplied with river water, which is generally far from being clear, and often imparts a disagreeable colour to clothes washed with it. Some years ago, a scheme was proposed by a chemist for filtering muddy water in any quantity. His method was, to have a large cask covered over in the bottom with straw to the depth of some inches, and then filled up with sand. This cask was entirely open at one end, and had a hole in the other, which, by means of a leaden pipe, communicated with a large reservoir of the water to be filtered, and which stood considerably higher than the cask. The water which descended through the pipe into the cask, having a tendency to rise up to the same level with that in the reservoir, would press violently against the sand, and, as he thought, run over the mouth of the cask perfectly filtrated, and free from its impurities. By this contrivance, indeed, a very violent pressure was occasioned, if the height of the reservoir was considerable: but the consequence was, not a filtration, but a greater degree of impurity in the water; for the sand was forced out of the cask along with it, and, however confined, the water always arose as muddy as it went in.

Where water is to be filtered in large quantity, as for the purposes of a family, a particular kind of soft spongy stones called *filtering stones*, are employed. These, however, though the water percolates through them very fine, and in sufficient quantity at first, are liable to be obstructed in the same manner as paper, and are then rendered useless. A better method seems to be, to have a wooden vessel, lined with lead, three or four feet wide at top, but tapering so as to end in a small orifice at the bottom. The under part of the vessel is to be filled with very rough sand, or gravel, well freed from earth by washing. Over this, pretty fine sand may be laid to the depth of 12 or 14 inches, but which must likewise be well freed from earthy particles. The vessel may then be filled up to the top with water, pouring it gently at first, lest the sand should be too much displaced. It will soon filter thro' the sand, and run out at the lower orifice exceedingly transparent, and likewise in very considerable quantity. When the upper part of the sand begins to be stopped up, so as not to allow

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a free paſſage to the water, it may occaſionally be taken off, and the earthy matter waſhed from it, when it will be equally ſerviceable as before.

570 Precipitation.

III. Precipitation or Coagulation. This operation is the very reverſe of ſolution, and is the bringing a body ſuddenly from a fluid to a ſolid ſtate. It differs from cryſtallization, in that it generally requires leſs time; and in cryſtallization the ſubſtance aſſumes regular figures, whereas precipitates are always in the form of powders.

Precipitation is generally preceded by ſolution and filtration: it is uſed for ſeparating earths and metals from the acids which had kept them ſuſpended. When a precipitation is made of the more valuable metals, glaſs veſſels are to be uſed. When earths, or the imperfect metallic ſubſtances, are to be precipitated in large quantity, wooden ones anſwer every purpoſe. If a metal is to be precipitated by an alkali, this ſalt muſt firſt be diſſolved in water, then filtered, and gradually added to the metallic ſolution. If particular circumſtances do not forbid, the ſalt for precipitation ſhould be choſen in its cauſtic ſtate, or deprived of its fixed air, becauſe then a very troubleſome effervescence is avoided. To promote the operation alſo, the mixture, if contained in a glaſs, is to be ſhaken; or if in any other veſſels, to be well ſtirred after every addition of alkali. If an earth is employed to precipitate a metal, the mixture muſt be in a manner conſtantly ſtirred or ſhaken, in order to promote the precipitation; and if one metal is to be precipitated by another, that which is uſed as a precipitant muſt be beaten into thin plates, that ſo they may be frequently cleaned from the precipitating metal, which would otherwiſe very ſoon totally impede the operation.

Sometimes a precipitation enſues on the addition of water or ſpirit of wine: but in moſt caſes care muſt be taken not to add too much of the ſubſtance which is uſed to precipitate the other; becauſe, in ſuch a caſe, the precipitate may be diſſolved after it has been thrown down. Thus, though volatile alkali will ſeparate copper from aquafortis, it will as effectually diſſolve the precipitate, if too much of it is uſed, as the acid itſelf. It is proper, therefore, to proceed cautiouſly, and examine a ſmall quantity of the liquor from time to time. If an addition of the precipitant throws down any more, it will be proper to add ſome more to the whole ſolution.

571 Edulcoration.

It is ſeldom or never that precipitation can be performed ſo perfectly, but that one or other of the ingredients will prevail; and though they ſhould not, a new compound, conſiſting of the acid united with the alkali, or other ſubſtance uſed for precipitation, is contained in the liquor through which the precipitate falls. It is proper, therefore, to waſh all precipitates; otherwiſe they can never be obtained perfectly pure, or free from a mixture of ſaline ſubſtances. This is beſt done by pouring the whole into a filter, and letting the fluid part run off, as long as it will drop, without ſhaking the cloth. Some water is then to be cautiouſly poured all over the ſurface of the precipitate, ſo as to diſturb it as little as poſſible. This water will puſh before it the ſaline liquor which is mixed with the powder, and render it much purer than before. A ſecond or third quantity of water may be uſed, in order to waſh off all the ſaline matter. This is called *edulcorating* the precipitate.

572 Evaporation.

IV. Evaporation. This operation conſiſts in diſſipating the moiſt fluid or volatile parts of any ſubſtance by means of heat. It moſt generally ſucceeds ſolution and filtration, being a preparatory for the operation of cryſtallization.

For the evaporation of ſaline ſolutions, which have been already filtered, and which it is of conſequence to preſerve from even the leaſt impurities, diſtilling veſſels are unqueſtionably the moſt proper; both as, by their means, the ſolution will be kept perfectly free from duſt, and as the quantity of liquor evaporated can be known with certainty by meaſuring that which comes over. This alſo is probably the moſt expeditious method of evaporating, and which requires the leaſt fuel. (See the detached articles Evaporation and Distillation). With regard to veſſels for evaporation, the ſame thing muſt be applicable which was mentioned above under *Solution*. No ſaline liquor muſt be evaporated in a veſſel which would be corroded by it; and hence iron veſſels are abſolutely improper for evaporations of any kind of ſaline liquor whatever.—Lead is in this caſe the metal moſt generally uſeful. It muſt only be uſed, however, where the evaporation is not carried to dryneſs; for, on account of the great fuſibility of this metal, nothing could be exſiccated in it without great danger of its melting. Where a ſaline liquor therefore is to be perfectly exſiccated, the evaporation, if performed in lead veſſels, muſt be carried on ſo far only as to form a ſaline pellicle on the ſurface of the liquor. It is then to be drawn off; for which purpoſe, all evaporating veſſels ſhould have a cock near the bottom. The liquor muſt now be put into a number of ſtone-ware baſons, ſet on warm ſand, where the exſiccation may be finiſhed.

573 Cryſtallization.

V. Crystallization. This, though commonly accounted one of the proceſſes in chemiſtry, is in reality only a *natural* one, and which the chemiſt can only prepare for, leaving the operation entirely in the hands of nature.—By cryſtallization is meant the ſeparation of a ſalt from the water in which it has been diſſolved, in tranſparent maſſes regularly figured, and differently formed, according to the different nature of the ſalts.

This proceſs depends upon the conſtitution of the atmoſphere more than any other; and therefore is difficult to be performed, nor does it always ſucceed equally well; neither have there yet been laid down any rules whereby beautiful and regular cryſtals can with certainty be formed at all times.

As the different ſalts aſſume very different figures when cryſtallized, they are not ſubject to the ſame general rules in cryſtallization. Nitre, Glauber's ſalt, vitriol of iron, and many others, cryſtallize beſt on having their ſolutions ſet in a cold place after proper evaporation. Sal polychreſt, and common ſalt, require the ſolution to be kept as hot as the hand can bear it during the time of cryſtallizing. Soluble tartar too, and other deliqueſcent ſalts, require to be kept warm while this operation is going on: and there are many ſaline ſubſtances, ſuch as the combinations of calcareous earths and magneſia with acids, which can ſcarcely be cryſtallized at all.

Mr Beaumé has diſcovered, that when two or more

ſalts are diſſolved in the ſame quantity of water, when one cryſtallizes, the cryſtals of that ſalt will not contain the leaſt quantity of any of the others: neither, although the liquor was acid or alkaline, will the cryſtals for that reaſon be either acid or alkaline, but will remain perfectly neutral; and the acid or alkaline liquor which adheres to the outſide of the cryſtals may be abſorbed by merely ſpreading them on filtering paper.—Hence we are furniſhed with a better method of ſhooting ſalts into large and well formed cryſtals than merely by diſſolving them in water; namely, by adding to the ſolutions, when ſet to cryſtallize, a certain quantity of acid or alkaline liquor, according to the nature of the ſalts themſelves. Theſe additions, however, are not equally proper for all ſalts; and it is not yet determined what kinds of ſalts ought to be cryſtallized in alkaline, and what in acid liquors.—Soluble tartar and Seignette's ſalt cryſtallize beſt when the liquor is alkaline. Sal ſedativus, ſal Glauberi, and ſal polychreſt, require an acid if cryſtallized in the cold; but ſal polychreſt forms into very fine and large cryſtals when the ſolution is alkaline, and kept as hot as the hand can eaſily bear.

The beſt general direction that can be given with regard to the regular cryſtallization of ſalts is, that they ought to be ſet to cryſtallize in as large a quantity at once as poſſible; and this, as far as we have obſerved, without any limit; for by this means, the cryſtals are formed much larger and better figured than they poſſibly can be by any other method hitherto known.—As to the form of the veſſels in which ſalts are to be cryſtallized, little can be ſaid with certainty. They are generally flat, and wider at top than at the bottom. The only proper material, in the large way, is lead.

574 Diſtillation.

VI. Distillation. This is a kind of evaporation; only in ſuch a manner, that the part of the liquor evaporated is not diſſipated in the air, but preſerved by making the ſteam paſs through a ſpiral pipe, which goes through a large veſſel full of cold water, or into cold glaſs receivers.

This is one of the moſt common chemical operations; and as there are a variety of ſubjects which require to be diſtilled, there is conſequently a conſiderable variety both in the form of the diſtilling veſſels to be uſed on different occaſions, and likewiſe in the materials of which they are made, as well as the management of the fire during the time of the operation.

Plate CXXXIV.

The moſt ſimple and eaſily performed diſtillation is that by the common copper ſtill, (fig. 3). It conſiſts of two parts; one called the *body*, and the other the *head*. The body is a cylindrical veſſel of copper, which is ſometimes tinned over in the inſide; but where diſtillation is performed without any regard to the reſiduum, the tinning is uſeleſs. The upper part of the body terminates in a kind of arch, in the middle of which is a circular aperture, about one half, or ſomething leſs, in diameter, of the breadth of the whole body.—Into this aperture, a round head, made likewiſe of copper, is fitted, ſo as to be removeable at pleaſure. In the top, or ſometimes in the ſide of the head, is inſerted a pewter pipe, which communicates with a ſpiral one of the ſame metal, that paſſes through a large wooden veſſel, called the *refrigeratory*, filled with cold water; each of its ends projecting a little above and below. The ſtill is to be filled two-thirds full of the ſubſtance to be diſtilled, the head put on, and the junctures well cloſed with mixture of linſeed meal and water, or common flour or chalk and water will anſwer the ſame purpoſe. This mixture is called the *luting*, or *lute*. A fire being kindled under the ſtill, the vapours will ariſe; and, being condenſed by the cold water, through which the ſpiral pipe called the *worm* paſſes, will run in a ſtream more or leſs ſtrong as the fire is more or leſs haſtily urged, and is catched in a receiver ſet underneath.

This kind of diſtilling veſſels is proper for procuring the eſſential oils of vegetables, vinous ſpirits from fermented liquor, and for the rectification of theſe after they are once diſtilled. Even the acetous acid may be very conveniently diſtilled in a copper veſſel, provided the worm and all the deſcending parts of the pipe which communicates with it be of pewter, otherwiſe a miſchievous impregnation of copper would be communicated to the diſtilled vinegar. The reaſon of this is, that copper is not diſſolved by vinegar, or in very ſmall quantity, when that acid is boiled in it; but if the metal is expoſed to the action of the acid, when cold, or to its vapours, a conſiderable diſſolution takes place. For this reaſon, too, the ſtill muſt be waſhed out after the operation while it continues hot, and muſt be very carefully freed from the leaſt remains of acid, otherwiſe it will be much corroded.

Copper-ſtills ought to be of as large a ſize as poſſible: but Dr Lewis very juſtly obſerves, that, in common ones, the width of the worm is by no means proportionable to the capacity of the ſtill: hence the vapour which iſſues from a large ſurface being violently forced through a ſmall tube, meets with ſo much reſiſtance as ſometimes to blow off the ſtill-head. This inconvenience is ridiculouſly endeavoured to be prevented by ſtrongly tying or otherwiſe forcing down the head; by which means, if the worm ſhould happen to be choaked up, a terrible exploſion would enſue: for no ligatures, or any other obſtacle whatever, have yet been found ſtrong enough to reſiſt the elaſtic force of ſteam, and the greater obſtacle it has to overcome, the greater would the exploſion be.—Dangers of this kind might be totally avoided by having the worm of a proper degree of wideneſs.

575 Mineral acids how diſtilled.

Sometimes, however, matters are to be diſtilled, ſuch as mineral acid ſpirits, which would corrode any kind of metalline veſſels; and for theſe only earths, or the cloſeſt kind of ſtone-ware, can be uſed. Theſe are more eaſily condenſed than the ſteams of aqueous or vinous liquors, and therefore do not require to be paſſed through a pipe of ſuch a length as is uſed for condenſing the ſteams from the common ſtill. In theſe caſes, where a violent heat is not neceſſary, and the diſtillation is to be performed in glaſs veſſels, the retort is uſed (fig. 4.) When a fluid is to be put into this veſſel, the retort muſt be laid upon its back on ſand, or any other ſoft matter that will ſupport it without breaking. A funnel muſt alſo be procured with a long ſtem, and a little crooked at the extremity, that the liquor may paſs at once into the belly of the retort, without touching any part of its neck; otherwiſe the quantity which adhered to the neck would paſs into the receiver when the retort was placed in a proper ſituation for diſtilling, and foul the produce. When the veſſel is properly filled, which ought never to be above two-thirds, it is to be ſet in a ſand-bath: that is, in an iron pot, of a proper thickneſs,

576 Retort.

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nefs, and covered over in the bottom, to the deph of one or two inches, with dry fand. When the retort is put in, fo as to ftand on its bottom, the pot is to be filled up with fand, as far as the neck of the retort. A glafs receiver is then to be applied, which ought to be as large as poffible, and likewife pretty ftrong; for which reafon it will be proper not to let the capacity of it be above what is neceffary to hold ten gallons. In the hinder part of it fhould be drilled a fmall hole, which may be occafionally fhut by a fmall wooden peg. The mouth of the receiver ought to be fo wide as to let the nofe of the retort enter to the middle of it, or very near to it; for if the vapours are difcharged very near the luting, they will act upon it much more ftrongly than when at a diftance. It is likewife proper to have the neck of the retort as wide as may be; for this has a very great effect in the condenfation, by prefenting a larger furface to the condenfing vapour.

577 Luting for acid fpirits.

The luting for acid fpirits ought to be very different from that ufed in other diftillations; for thefe will penetrate the common lutes fo as to make them liquid and fall down into the receiver. Some have ufed retorts the necks of which were ground to the receivers with emery; but thefe are very difficult to be procured, and are expenfive, and confequently have never come into a general ufe. Various kinds of lutes have been propofed, but the preference feems due to a mixture of clay and fand. We are not to underftand, however, that every kind of clay is fit for this purpofe: it muft only be fuch as is not at all, or very little, affected by acids; and this quality is only poffeffed by that kind of which tobacco-pipes is made. Trial ought to be made of this before the diftillation is begun, by pouring a little nitrous acid on the clay intended to be made ufe of. If a violent effervefcence is raifed, we may be fure that the clay is unfit for the purpofe. Finely powdered alabafter would anfwer extremely well, had it the ductility of clay. As this kind of lute remains foft for a confiderable time, it ought to be farther fecured by a bit of rag fpread with fome ftrong cement, fuch as quicklime mixed with the white of an egg, *&c.* Matters, however, ought to be managed in fuch a manner, that the luting may give way, rather than the veffel burft; which would not only occafion a certain lofs of the materials, but might endanger the perfons who are ftanding by.

578 *Balneum arenæ.*

The iron pots commonly ufed for diftillations by the fand-bath, or *balneum arenæ*, are commonly made very thick; and are to be fold at large founderies, under the name of *fand-pots*. The fhape of thefe, however, is by no means eligible: for, as they are of a figure nearly cylindrical, if the retort is of fuch a fize as almoft to fill their cavity, it cannot be put into them when full, and often pretty heavy, without great danger of touching the fides of the pot; and in this cafe, touching and *breaking* are fynonymous expreffions. It is much better, therefore, to have them in the figure of a punch-bowl; and the common caft-iron kettles, which may be had much cheaper than the fand-pots ufually fold, anfwer extremely well. If the diftilling veffel is placed in a pot filled with water, the diftillation is faid to be performed in a water-bath, or *balneum mariæ*.

When the matter to be condenfed is very volatile, a number of open receivers with two necks, called *adopters* (fig. 7.) may be ufed, with a clofe receiver at the end. Each of thefe adopters muft be luted with as much care as when only a fingle receiver is made ufe of. Veffels of a fimilar kind were formerly much ufed by chemifts for particular fublimations, under the name of *aludels*.

579 Adopters of aludels.

Formerly, inftead of retorts, a veffel called a *cucurbit*, (fig. 5, and 6.) with a head like the common ftill, called an *alembic*, were ufed; but the more fimple figure of the retort gives it greatly the preference. It is but feldom that veffels of this kind are ufeful, which will be taken notice of when defcribing the particular operations; and if at any time an alembic head fhould be neceffary, its ufe may be fuperfeded by a crooked glafs tube, which will anfwer the purpofe equally well.

Sometimes a very violent fire is required in diftillations by the retrot. Here, where it is poffible, glafs or earthen veffels fhould be avoided, and iron pots fubftituted in their ftead. The hardeft and beft caft iron, however, will at laft melt by a vehement heat; and therefore there is a neceffity for ufing earthen ware, or coated glafs. This laft is better than moft kinds of earthen ware, as being lefs porous; for when the veffel is urged by a very intenfe heat, the glafs melts, and forms a kind of femivitreous compound with the infide of the coating, fo that its figure is ftill preferved, and the accidental cracks in the luting are filled up.

580 Coating of glaffes.

For coating of veffels, mixtures of colcothar of vitriol, fand, iron filings, blood, chopped hair, *&c.* have been recommended. We cannot help thinking, however, that the fimple mixture of tobacco-pipe clay and fand is preferable to any other; efpecially if, as Dr Black directs, that part next the glafs is mixed with charcoal duft.

The proportions recommended by the Doctor for luting the joints of veffels, are four parts of fand and one of clay; but for lining the infides of furnaces, and we fhould think, likewife for coating glafs veffels, he directs 6 or 7 of fand to 1 of clay, that the contraction of the clay in drying may thereby be the more effectually prevented. Befides this, he directs a mixture of three parts of charcoal-duft with one of clay to be put next the furnace itfelf, as being more apt to confine the heat; but poffibly the firft compofition might be fufficient for glaffes.

The coating of large glaffes muft be a very troublefome and tedious operation; and therefore coated glafs is never ufed but in experiments. When large diftillations are to be performed in the way of trade, recourfe muft be had either to iron pots, or to earthen ware. Of the moft proper kinds of earthen ware for refifting violents heat, we fhall take notice under the article *Fufion.*

In all diftillations by the retort, a confiderable quantity of air, or other incondenfible vapour, is extricated; and to this it is abfolutely neceffary to give vent, or the veffel would be burft, or the receiver thrown off. For this purpofe, Dr Lewis recommends an open pipe to be inferted at the luting, of fuch an height as will not allow any of the vapour to efcape; but this we cannot approve of, as by that means a conftant communication is formed between the external atmofphere and the matters contained in the retort and receiver, which is at all times to be avoided as much as poffible, and in fome cafes, as the diftillation of phofphorus, would be very dangerous. The having a fmall

Chemical Operations. ſmall hole drilled in the receiver, which is to be now and then opened, muſt anſwer the purpoſe much better, although it takes more attendance; but if the operator is obliged to leave the veſſels for ſome time, it will be convenient either to leave the little hole open, or to contrive it ſo that the wooden peg may be puſhed out with leſs force than is ſufficient to break the lute.

581 Sublimation. VII. Sublimation. This, properly ſpeaking, is only the diſtillation of a dry ſubſtance; and therefore, when volatile matters, ſuch as ſalt of hartſhorn, are to be ſublimed, the operation is performed in a glaſs retort ſet in a ſand-bath; and the ſalt paſſes over into the receiver. The cucurbit and alembic were formerly much in uſe for this purpoſe; and a blind head, without any ſpout, was applied. A much ſimpler apparatus, however, is now made uſe of. A globe made of very thin glaſs, or an oblong veſſel of the ſame kind, anſwers the more common purpoſes of ſublimation. For experiments, Florence flaſks are excellent: as being both very cheap, and having the neceſſary ſhape and thinneſs requiſite for bearing the heat without cracking. The matter to be ſublimed muſt not, on almoſt any occaſion, take up more than a third part of the ſubliming veſſel. It is to be ſet in a ſand-bath, that the heat may be more equally applied than it could otherwiſe be. The heat muſt be no greater, or very little, than is neceſſary for ſublimation, or it will be in danger of flying out at the mouth of the ſubliming veſſel, or of choaking it up ſo as to burſt. The upper part of the veſſel, too, muſt by no means be kept cool, but ſlightly covered with ſand, that the matter may ſettle in a kind of half melted ſtate, and thus form a compact hard cake, which is the appearance ſublimates are expected to have. Hence this operation requires a good deal of caution, and is not very eaſily performed.

582 Deflagration. VIII. Deflagration. This operation is always performed by means of nitre, except in making the flowers of zinc. It requires open veſſels of earth or iron; the latter are very apt to be corroded, and the former to imbibe part of the matter. To perform this proceſs with ſafety, and without loſs, the nitre ought to be mixed with whatever matter is to be deflagrated with it, and thrown, by little and little into the veſſel previouſly made red-hot. If much is put in at once, a great deal will be thrown out by the violent commotion; and to perform this operation in cloſe veſſels is in a manner impoſſible, from the prodigious quantity of elaſtic vapour generated by the nitre. Care muſt alſo be taken to remove the whole mixture to ſome diſtance from the fire, and not to bring back any ſpark from the quantity deflagrating, with the ſpoon which puts it in; otherwiſe the whole would irremediably be conſumed at once.

583 Calcination. IX. Calcination. This is the ſubjecting any matter to a heat ſo violent as to diſſipate ſome part of it, without melting what remains. It is often practiſed on metallic ſubſtances, particularly lead, for obtaining the calx of that metal called *minium*, or red lead.

This operation, as indeed all other chemical ones, is beſt performed in large quantities, where a particular furnace is conſtructed on purpoſe, and a fire kept on day and night without interruption. The flame is made to play over the ſurface of the metal, and it is continually ſtirred ſo as to expoſe different parcels of it to the action of the heat.

584 Fuſion. X. Fusion. This is when a ſolid body is expoſed to ſuch a degree of heat as makes it paſs from a ſolid to a fluid ſtate; and as different ſubſtances are poſſeſſed of very different degrees of fuſibility, the degrees of melting heat are very various.

Beſides the true fuſion, there are ſome kinds of ſalts which retain ſo large a proportion of water in their cryſtals, as to become entirely fluid upon being expoſed to a very ſmall degree of heat. This is commonly called the *watery fuſion*; but is really a *ſolution* of the ſalt in that quantity of water retained by it in its cryſtalline form: for ſuch ſalts afterwards become ſolid by the evaporation of the water they contained: and then require a ſtrong red heat to melt them thoroughly, or perhaps are abſolutely infuſible.

Of all known ſubſtances, unctuous and inflammable ones become fluid with the leaſt heat: then come the more fuſible metals, lead, tin, and antimony; then ſome of the more fuſible ſalts; and then the harder metals, ſilver, gold, copper, and iron; then the mixtures for making glaſs; and laſt of all, the metal called *platina*, which has hitherto been incapable of fuſion, except by the violent action of the ſun-beams in the focus of a large burning glaſs. This ſubſtance ſeems to be the moſt refractory of all others, even the hardeſt flints melting into glaſs long before it. (See Platina.)

Fuſion of ſmall quantities of matter is uſually performed in pots called *crucibles*; which, as they are required to ſtand a very violent heat, muſt be made of the moſt refractory materials poſſible.

585 Crucibles, proper materials for. The making of crucibles belongs properly to the potter: but as a *chemiſt* ought to be the judge of their compoſition, we ſhall here give ſome account of the different attempts to make theſe veſſels of the neceſſary ſtrength.

All earthen veſſels are compoſed, at leaſt partly, of that kind which is called the *argillaceous earth* or *clay*, becauſe theſe only have the neceſſary ductility, and can be formed into veſſels of the proper form. Pure clay is, by itſelf, abſolutely unfuſible; but is exceedingly apt to crack when expoſed to ſudden changes of heat and cold. It is alſo very apt to melt when mixed with other ſubſtances, ſuch as calcareous earths, &c. When mixed in a certain proportion with other materials, they are changed with violent heat into a kind of half-melted ſubſtance, ſuch as our ſtone-bottles. They cannot be melted completely, however, by almoſt any fire; they are alſo very compact, and will contain the moſt fuſible ſubſtances, even glaſs of lead itſelf; but as they are very apt to crack from ſudden changes of heat and cold, they are not ſo much uſed; yet, on particular occaſions, they are the only ones which can be made uſe of.

The more denſe any kind of veſſels are, the more apt they are, in general, to break by a ſudden application of heat or cold: hence crucibles are not, in general, made of the greateſt denſity poſſible: which is not at all times required. Thoſe made at Heſſe, in Germany, have had the beſt reputation for a long time. Mr Pott, member of the Academy of Sciences at Berlin, hath determined the compoſition of theſe crucibles to be, one part of good refractory clay, mixed with two parts of ſand, of a middling fineneſs, from which the fineſt part has been ſifted. By ſifting the finer particles from the ſand, too great compactneſs is avoided:

but at the ſame time this mixture renders them apt to be corroded by vitrifying matters kept a long time in fuſion; for theſe do not fail to act upon the ſand contained in the compoſition of the crucible, and, forming a vitreous maſs, at laſt run through it.

This inconvenience is prevented, by mixing, inſtead of ſand, a good baked clay in groſs powder. Of a compoſition of this kind are made the glaſs-houſe pots, which ſometimes ſuſtain the violent heat employed in making glaſs for ſeveral months. They are, however, gradually conſumed by the glaſs, and become conſtantly more and more thin.

586 Platina, a deſirable material.

As the containing veſſel, however, muſt always be expoſed to a more violent heat than what is contained in it, crucibles ought to be formed of ſuch materials as are not vitrifiable by the heat of any furnace whatever. But from the attempts made to melt platina, it appears, that of all known ſubſtances it would be the moſt deſirable for a melting veſſel. Heſſian crucibles, glaſs-houſe pots, Sturbridge clay, in ſhort every ſubſtance which could be thought of to reſiſt the moſt violent heat, were melted in ſuch a manner as even to ſtop up the pipes of large bellows, while platina was not altered in the leaſt; and Meſſrs Macquer and Beaume have ſhown, that though platina cannot be melted ſo as to caſt veſſels of it, it may nevertheleſs be cupelled with lead ſo as to become malleable, and thus veſſels might otherwiſe be made

587 Achard's method of making crucibles of platina.

from that ſubſtance. The extreme ſcarcity of this mineral, however, leaves as yet little room to hope for any thing from it, though Mr Achard has found a method of forming crucibles from this refractory ſubſtance. It conſiſts in moulding the precipitate made with ſal ammoniac into the form of a crucible, and then applying a ſudden and very violent heat, which fuſes this calx.

Mr Pott has made ſo many experiments upon clays mixed with different ſubſtances, that he has in a manner exhauſted the ſubject. The baſis of all his compoſitions was clay. This he mixed in different proportions with metallic calces, calcined bones, calcareous earths, talcs, amianthus, aſbeſtus, pumice-ſtones, tripoli, and many others; but he did not obtain a perfect compoſition from any of them. The beſt crucibles, according to Scheffer, cannot eaſily contain metals diſſolved by ſulphur, in the operation of parting by means of ſulphur. They may be made much more durable and ſolid, by ſteeping them a few days in linſeed-oil, and ſtrewing powdered borax upon them before they are dried.

588 Mr Pott's directions.

The reſult of Mr Pott's experiments are: 1. Crucibles made of fat clays are more apt to crack when expoſed to ſudden heat, than thoſe which are made of lean or meagre clays. *Meagre clays* are thoſe which contain a conſiderable quantity of ſand along with the pure argillaceous earth: and *fat clays* are thoſe which contain but little. 2. Some crucibles become porous by long expoſure to the fire, and imbibe part of the contained metals. This may be prevented, by glazing the internal and external ſurfaces; which is done by moiſtening theſe with oil of tartar, or by ſtrewing upon them, when wetted with water, powdered glaſs of borax. Theſe glazings are not capable of containing glaſs of lead. 3. Crucibles made of burnt clay groſsly powdered, together with unburnt clay, were much leſs liable to crack by heat than crucibles made of the ſame materials where the burnt clay was finely powdered, or than crucibles made entirely of unburnt clay. 4. If the quantity of unburnt clay be too great, the crucible will be apt to crack in the fire. Crucibles made of 10 ounces of unburnt clay, 10 ounces of groſsly powdered burnt clay, and three drachms of calcined vitriol, are capable of retaining melted metals, but are pervaded by glaſs of lead. The following compoſition is better than the preceding: Seven ounces of unburnt clay, 14 ounces of groſsly powdered burnt clay, and one drachm of calx of vitriol. Theſe crucibles may be rendered more capable of containing glaſs of lead, by lining their internal ſurfaces, before they are baked, with unburnt clay diluted with water. They may be further ſtrengthened by making them thicker than is uſually done; or by covering their external ſurfaces with ſome unburnt clay, which is called *arming* them. 5. The compoſition of crucibles moſt capable of containing the glaſs of lead, was 18 parts of groſsly powdered burnt clay, as much unburnt clay, and one part of fuſible ſpar. Theſe crucibles muſt not, however, be expoſed too ſuddenly to a violent heat. 6. Crucibles capable of containing glaſs of lead very well, were made of 24 parts of unburnt clay, four parts of burnt clay, and one part of chalk. Theſe require to be armed. 7. Plume alum powdered, and mixed with whites of eggs and water, being applied to the internal ſurface of a Heſſian crucible, enabled it to retain for a long time glaſs of lead in fuſion. 8. One part of clay, and two parts of Spaniſh chalk, made very good crucibles. The ſubſtance called *Spaniſh chalk* is not a calcareous earth, but appears to be a kind of ſteatites. 9. Two parts of Spaniſh chalk, and one part of powdered tobacco-pipes, made good lining for common crucibles. 10. Eight parts of Spaniſh chalk, as much burnt clay, and one part of litharge, made ſolid crucibles. 11. Crucibles made of black lead are fitter than Heſſian crucibles for melting metals; but they are ſo porous, that fuſed ſalts paſs entirely thro' them. They are more tenacious than Heſſian crucibles, are not ſo apt to burſt in pieces, and are more durable. 12. Crucibles placed with their bottoms upwards, are leſs apt to be cracked during the baking, than when placed differently. 13. The paſte of which crucibles are made, ought not to be too moiſt; elſe, when dried and baked, they will not be ſufficiently compact: hence they ought not to be ſo moiſt as to be capable of being turned on a potter's lathe; but they muſt be formed in braſs or wooden moulds.

589 Materials moſt capable of reſiſting glaſs of lead.

590 Dr Lewis's obſervations.

On this ſubject Dr Lewis hath alſo made ſeveral obſervations; the principal of which are, 1. Pure clay ſoftened to a due conſiſtence for being worked, not only coheres together, but ſticks to the hands. In drying, it contracts 1 inch or more in 12; and hence it is very apt to crack, unleſs it is dried exceeding ſlowly. In burning, it is ſubject to the ſame inconvenience, unleſs very ſlowly and gradually heated. When thoroughly burnt, if it has eſcaped thoſe imperfections, it proves ſolid and compact; and ſo hard as to ſtrike fire with ſteel. Veſſels made of it are not penetrated by any kind of liquid; and reſiſt ſalts and glaſſes brought into the thinneſt fuſion, excepting thoſe which by degrees corrode and diſſolve the earth itſelf, as glaſs of lead; and even this penetrating glaſs is reſiſted by it better than by almoſt any other earth; but, in counterbalance to theſe good qualities, they cannot be heated or cooled, but with ſuch precautions as can

rarely be complied with in the way of buſineſs, without cracking, or flying in pieces.

2. Clay that has been once expoſed to any conſiderable degrees of heat, and then powdered, has no longer any tenacity. Freſh clay, divided by a due proportion of this powder, proves leſs tenacious than by itſelf; not ſticking to the hands, though cohering ſufficiently together. It ſhrinks leſs in drying, is leſs apt to crack, and leſs ſuſceptible of injury from alterations of heat and cold; but at the ſame time is leſs ſolid and compact. Conſiderable differences are obſerved in theſe reſpects; not only according to the quantity of dividing matter, but according as it is in finer or coarſer powder.

3. Veſſels made with a moderate proportion of fine powder, as half the weight of the clay, are compact and ſolid, but ſtill very apt to crack, from ſudden heat or cold: thoſe with a larger proportion, as twice or thrice the quantity of the clay, are free from that imperfection, but ſo friable as to crumble between the fingers. Nor does there appear to be any medium between a diſpoſition to crack and to crumble; all the compounds made of clay and fine powders having the one or the other, or both imperfections. Coarſer powders of the ſize of middling ſand, form, with an equal weight of clay, compounds ſufficiently ſolid, and much leſs apt to crack than the mixtures with fine powders. Two parts of coarſe powder, and one of clay, prove moderately ſolid, and but little diſpoſed to crack: a mixture of three parts and one, tho' heated and cooled ſuddenly, does not crack at all, but ſuffers very fluid ſubſtances to tranſude through it; ſolidity, and reſiſtance to quick viciſſitudes of heat and cold, ſeeming here alſo to be incompatible.

4. Pure clay, mixed with pure clay that has been burnt, is no other than one ſimple earth; and is neither to be melted nor ſoftened, nor made in any degree tranſparent with the moſt intenſe fires.

5. Mixtures of clay with gypſeous earths burn whiter than clay alone; in certain proportions, as two parts of clay to three of gypſum, they become, in a moderate fire, ſemi-tranſparent, and in a ſtrong one they melt.

6. Calcareous earths in ſmall proportion bake tolerably compact and white; and added to other compoſitions, ſeem to improve their compactneſs. If the quantity of the calcareous earth nearly equals that of the clay, the mixture melts into a yellow glaſs; if it conſiderably exceeds, the product acquires the qualities of quicklime.

7. Veſſels made from clay and ſand, in whatever proportion, do not melt in the ſtrongeſt fire; but they ſometimes bend or ſoften, ſo as to yield to the tongs. Glaſſes in thin fuſion penetrate them by diſſolving the ſand. If gypſeous or calcareous earths e urged in ſuch crucibles with a vehement heat, the veſſels and their contents run all into one maſs. In moderate fires, theſe veſſels prove tolerably compact, and retain moſt kinds of ſalts in fuſion: but they are liable to crack, eſpecially when large; and do not long ſuſtain melted metals, being burſt by their weight. Such are the Heſſian crucibles.

8. Mixtures of clay and black-lead, which ſeems a ſpecies of talc, are not liable to crack from alternations of heat and cold; but are extremely porous. Hence black-lead crucibles anſwer excellently for the melting of metals, and ſtand repeated fuſions; whilſt ſalts flowing thin, tranſude through them almoſt as water through a ſieve: ſulphureous bodies, as antimony, corrode them.

9. Pure clay, ſoftened with water, and incruſtated on earthen veſſels, that have been burnt, does, not adhere to them, or ſcales off again upon expoſure to the fire; applied to unburnt veſſels, it adheres and incorporates. Divided clay unites with them in both ſtates. Vitreous matters, melted in veſſels of pure clay, adhere ſo firmly as not to be ſeparated; from veſſels of divided clay they may be knocked off by a hammer.

10. The ſaline fluxes which promote the fuſion of clay, beſides the common ones of all earths, alkali and borax, are chiefly arſenic fixed by nitre, and the fuſible ſalt of urine; both which have little effect on the other earths though mixed in a lager proportion. Nitre, which readily brings the cryſtalline earths into fuſion, and ſal mirabile and ſandiver, powerful fluxes for the calcareous earths, do not perfectly vitrify with clay. Burnt clay does not differ in theſe reſpects from ſuch as has not been burnt; nor in that ſingular property of vitrifying with gypſeous or calcareous earths, without any ſaline or metallic addition; the utmoſt vehemence of fire ſeeming to deſtroy only its ductility, or that power by which it coheres when its parts are moiſtened with water.

591 More perfect veſſels to be hoped for from porcelain.

But though it ſeems impoſſible to make perfect veſſels from mixtures of clay in its two different ſtates, of burnt and unburnt, more is to be hoped from the mixtures which are employed in making porcelain. Manufactories of this kind of ware have been attempted in different countries, (ſee PORCELAIN); and in ſome places the qualities requiſite for chemical veſſels have been given to it in a very ſurpriſing degree. The count de Lauraguais, a French nobleman, and member of the academy of ſciences, has diſtinguiſhed himſelf in a very eminent manner by attempts of this kind. The tranſlator of the chemical dictionary aſſures us, that he had it from a gentleman of undoubted veracity, that this nobleman having heated a piece of his porcelain red hot, threw it into cold water, without breaking or cracking it.

592 Mr Reaumur's porcelain.

The moſt uſeful attempt, however, for the purpoſes of chemiſtry, ſeems to be the diſcovery by Mr Reaumur of converting common green glaſs into porcelain. This was publiſhed as long ago as the year 1739; yet we have ſcarce heard of any chemiſt, no not Dr Lewis himſelf, who has made trial of chemical veſſels formed of this ſort of porcelain, although the very uſe to which Mr Reaumur thought the preparation could be applicable was that of bringing chemical veſſels to a degree of perfection which could not otherwiſe be done. The following is the reſult of Mr Reaumur's experiments.

Green glaſs, ſurrounded with white earthy matters, as white ſand, gypſum, or plaſter of Paris, *&c.* and expoſed to a conſiderable heat not ſtrong enough to alter its figure, as that of a potter's furnace, acquires different ſhades of blue, and by degrees begins to grow white. On breaking the glaſs, the white coat appears to be compoſed of fine, white, gloſſy, ſatinlike fibres, running tranſverſely, and parallel to one another; the glaſs in the middle being ſcarcely altered. On continuing the cementation, the change proceeds further and further, till at length the white fibrous parts

parts from both ſides meet in the middle, and no appearance of glaſs remains. By this means, entire veſſels of glaſs may be changed into procelain.

The ſubſtance into which glaſs is thus converted, is opaque, compact, internally of great whiteneſs, equal to that of the fineſt china-ware; but, externally, of a much duller hue. It is conſiderably harder than glaſs, much leſs fuſible in the fire, and ſuſtains alterations of heat and cold without injury. Veſſels of it, cold, bear boiling liquors; and may be placed on the fire at once, without danger of their cracking. "I have put a veſſel of this porcelain (ſays the author) into a forge, ſurrounded it with coals, and kept vehemently blowing for near a quarter of an hour; I have melted glaſs in this veſſel, without its having ſuffered any injury in its figure." If means could be found of giving the outſide a whiteneſs, equal to the internal part, glaſs veſſels might thus be converted into a valuable kind of porcelain ſuperior to all that have hitherto been made. Chemiſtry, ſays he, may receive from this diſcovery, in its preſent ſtate, ſuch veſſels as have been long wanted; veſſels which, with the compactneſs and impenetrability of glaſs, are alſo free from its inconveniences.

The common green glaſs bottles yield a procelain of tolerable beauty; window-glaſſes, and drinking-glaſſes, a much inferior one; while the finer kinds of cryſtalline glaſſes afforded none at all. With regard to the cementing materials, he found white ſand and gypſum, or rather a mixture of both, to anſwer beſt. Coloured earths generally make the external ſurface of a deeper or lighter brown colour; ſoot and charcoal, of a deep black, the internal part being always white.

593 Dr Lewis's experiments.

The account of this kind of porcelain given by Mr Reaumur, induced Dr Lewis, who had alſo obſerved the ſame changes on the bottom of glaſs-retorts expoſed to violent heat in a ſand-bath, to make further experiments on this matter; an account of which he has publiſhed in his *Philoſophical Commerce of Arts*. The reſults of his experiments were, 1. Green glaſs, cemented with white ſand, received no change in a heat below ignition. 2. In a low red heat, the change proceeded exceeding ſlowly; and in a ſtrong red heat, approaching to white, the thickeſt pieces of glaſs bottles were thoroughly converted in the ſpace of three hours. 3. By continued heat, the glaſs ſuffered the following progreſſive changes: firſt, its ſurface became blue, its tranſparency was diminiſhed, and a yellowiſh hue was obſervable when it was held between the eye and the light. Afterwards it was changed a little way on both ſides into a white ſubſtance, externally ſtill bluiſh; and, as this change advanced ſtill further and further within the glaſs, the colour of the vitreous part in the middle approached nearer to yellow: the white coat was of a fine fibrous texture, and the fibres were diſpoſed nearly parallel to one another, and tranſverſe to the thickneſs of the piece: by degrees the glaſs became white and fibrous throughout, the external bluiſhneſs at the ſame time going off, and being ſucceeded by a dull whitiſh or dun colour. By a ſtill longer continuance in the fire, the fibres were changed gradually from the external to the internal part, and converted into grains; and the texture was then not unlike that of common porcelain. The grains, at firſt fine and ſomewhat gloſſy, became by degrees, larger and duller; and at laſt the ſubſtance of the glaſs became porous and friable, like a maſs of white ſand ſlightly cohering. 4. Concerning the qualities of this kind of porcelain, Dr Lewis obſerves, that, while it remained in the fibrous ſtate, it was harder than common glaſs, and more able to reſiſt the changes of heat and cold than glaſs, or even porcelain; but, in a moderate white heat, was fuſible into a ſubſtance not fibrous, but vitreous and ſmooth, like white enamel; that when its texture had become coarſely granulated, it was now much ſofter and unfuſible: and laſtly, that when ſome coarſely grannlated unfuſible pieces, which, with the continuance of a moderate heat, would have become porous and friable, were ſuddenly expoſed to an intenſe fire, they were rendered remarkably more compact than before; the ſolidity of ſome of them being ſuperior to that of any other ware.

594 This ſubject ſtill imperfect.

It ſeems ſurpriſing that this able chemiſt, who on other occaſions had the improvements of the arts ſo much at heart, did not put ſome veſſels of this kind of porcelain to other ſevere trials, beſides attempting to fuſe it by itſelf with a violent fire: for though pieces of it were abſolutely unfuſible, we are not ſure but they might have been corroded by alkaline ſalts, acids, calcareous earths, or glaſs of lead; nay, it ſhould ſeem very probable that they would have been ſo: in which caſe they would not be much ſuperior to the veſſels made from earthy materials. When a firſt-rate chemiſt publiſhes any thing in an imperfect ſtate, inferior ones are diſcouraged from attempting to finiſh what he has begun; and thus, notwithſtanding that theſe experiments have been ſo long publiſhed, nobody has yet attempted to inveſtigate the properties of this kind of porcelain, by getting chemical veſſels made of it, and trying how they anſwer for crucibles, or retorts.

All that has been ſaid concerning the proper materials for crucibles, muſt likewiſe be applicable to the materials for retorts, which are required to ſtand a very violent heat. Mr Reaumur's porcelain bids faireſt for anſwering the purpoſe of retorts as well as crucibles. The great diſadvantage of the common, earthen ones, is, that they ſuffer a quantity of volatile and penetrating vapours to paſs through them. This is very obſervable in the diſtillation of phoſphorus; and though this ſubſtance has not hitherto been uſed for any purpoſe in medicine, and very little in the arts, its acid only being ſometimes uſed as a flux, if veſſels could be made capable of confining all the ſteams and at the ſame time bearing the heat neceſſary for its diſtillation, phoſphorus, perhaps, might be obtained in ſuch quantity, as to ſhow that it is a preparation not altogether uſeleſs.

595 [596] Stone-ware veſſels corroded.

With regard to ſtone-ware veſſels, and all thoſe into which the compoſition of ſand or flint enters, we ſhall only further obſerve, that they will be corroded by fixed alkaline ſalts, eſpecially of the cauſtic kind, in a very moderate heat. Dr Black, having evaporated ſome cauſtic ley in a ſtone-ware baſon, and then melted the dry ſalt in the ſame veſſel, found it ſo corroded, as afterwards to be full of ſmall holes; and he found nothing to reſiſt the action of this ſalt ſo well as ſilver.

597 Wedgewood's ware.

On the ſubject of chemical veſſels, we have now, however, to add the improved earthen ware of Mr Wedgewood; in which the properties of compactneſs, infuſibility and the power of reſiſting ſudden changes of heat and cold, are ſaid to be united, ſo that it promiſes to be a very valuable addition to the chemical apparatus.

598 Maceration. 11. Maceration, or Digestion. This is the mixing two bodies, generally a ſolid and a fluid, together, and then expoſing them to a moderate degree of heat for a conſiderable length of time, that ſo they may have the better opportunity of acting upon one another. Digeſtion is uſually performed in the glaſſes already mentioned, called *matraſſes* or *bolt-heads*; and is done in a ſand-heat. When any of the ſubſtances are very volatile, as ſpirit of wine; or when the matter requires to be heated ſo conſiderably that a quantity of vapour will be raiſed, the necks of the bolt-heads ought to be pretty long; or a tin pipe may be inſerted, of ſufficient length to prevent the eſcape of any part of the ſteam.

599 Levigation. 12. Levigation. This is the reducing any body to a very fine powder, which ſhall feel quite ſoft between the fingers or when put into the mouth. It is performed by grinding the ſubſtance upon a flat marble ſtone, with ſome water, or by rubbing it in a marble mortar. In the large way, levigation is performed by mills drawn by horſes, or driven by water; ſome of them are ſo ſmall as to be turned by the hand. They conſiſt of two ſmooth ſtones, generally of black marble, or ſome other ſtone equally hard, having ſeveral grooves in each, but made to run in contrary directions to one another when the mill is ſet in motion. The matter being mixed with water, is put in by a funnel, which is fixed into a hole in the upper ſtone, and turns along with it. The under milſtone has round it a wooden ledge, whereby the levigating matter is confined for ſome time, and at length diſcharged, by an opening made for that purpoſe, when it has accumulated in a certain quantity.

In this operation, when the matters to be levigated are very hard, they wear off a part of the mortar, or ſtones on which they are levigated; ſo that a ſubſtance perfectly hard, and which could not be worn by any attrition, is as great a deſideratum for the purpoſes of levigation, as one which could not be melted is for thoſe of fuſion. Dr Lewis propoſes the porcelain of Mr Reaumur as an improvement for levigating planes, mortars, *&c.* becauſe, while in its fibrous ſtate, it is conſiderably harder than glaſs, and conſequently much leſs liable to abraſion by the harder powders.

In many caſes levigation is very much accelerated by what is called *elutriation*. This is the method by which many of the painters colours are prepared of the requiſite fineneſs; and is performed by mixing any ſubſtance not totally reduced to the neceſſary degree of fineneſs, with a ſufficient quantity of water, and ſtirring them well together. The finer parts of the powder remain ſome time ſuſpended in the water, while the groſſer particles fall to the bottom. The ſeparation is then eaſily made, by pouring off the water impregnated with theſe fine parts, and committing the reſt to the levigating mill, when it may again be waſhed; and this may be repeated till all the powder is reduced to the utmoſt fineneſs. Subſtances ſoluble in water cannot be levigated in this manner.

Of Chemical Furnaces.

The two general diviſions we have already mentioned of thoſe who practice chemiſtry, namely, thoſe who have no other view than mere experiment, and thoſe who wiſh to profit by it, render very different kinds of furnaces neceſſary. For the firſt, thoſe furnaces are neceſſary which are capable of acting upon a ſmall quantity of matter, yet ſufficient for all the changes which fire can produce from ſimple digeſtion to the moſt perfect vitrification. For the others, thoſe are to be choſen which can produce the ſame changes upon very large quantities of matter, that as much may be done at once as poſſible.

600 Portable furnace. To avoid the trouble and expence of a number of furnaces, a portable one hath long been a deſideratum among thoſe chemiſts who are fond of making experiments. One of the beſt of thoſe, if not the very beſt, that hath yet appeared, is that deſcribed in Shaw's edition of Boerhaave's chemiſtry, and repreſented fig. 1. Plate CXXXIV.

This furnace is made of earth; and, as the workmanſhip of a furnace requires none of the neatneſs or elegance which is required in making potters veſſels, any perſon may eaſily make a furnace of this kind for himſelf, who has time and patience for ſo doing. With regard to the moſt proper materials, all that we have ſaid concerning crucibles and retorts muſt be applicable to the materials for conſtructing a furnace; only here we need not care ſo much for the poroſity, or diſpoſition to crumble, as when crucibles or other diſtilling veſſels are to be made.

Plate iron is commonly directed for the outſide of portable furnaces; but we cannot help thinking this is a very needleſs expence, ſeeing the coating which it neceſſarily requires on the inſide may be ſuppoſed to harden to ſuch a degree as ſoon to ſupport itſelf, without any aſſiſtance from the plate-iron. This will be the leſs neceſſary, if we conſider, that, for the thickneſs of the walls of any furnace where a conſiderable heat is wanted, two or three inches are by no means ſufficient. When the inſide of a furnace is heated, the walls, if very thin, are ſoon penetrated by the heat, and great part of it by this means diſſipated in the air. If they are of a ſufficient thickneſs, the heat cannot penetrate ſo eaſily; and thus the inner part of the furnace preſerves the heat of the fuel, and communicates it to the contained veſſel. In the conſtruction of a portable furnace, therefore, it will be convenient to have all parts of it ſix inches thick at leaſt. This will alſo give it a ſufficient degree of ſtrength; and, as it is formed of ſeveral different peices, no inconvenience can follow from the weight of each of them taken ſeparately.

In Boerhaave's chemiſtry, this furnace is repreſented as narrower at the bottom than at the top; but we cannot ſuppoſe any good reaſon for ſuch a form, ſeeing a cylindrical one muſt anſwer every purpoſe much better, as allowing a larger quantity of air to paſs through the fuel, and likewiſe not being ſo apt to be overturned as it neceſſarily muſt be where the upper part is conſiderably heavier than the lower. We have, therefore, given a repreſentation of it as of a cylindrical form.

The furnace conſiſts of five or more parts. C, repreſents the dome, or top of the furnace, with a ſhort earthen funnel E for tranſmitting the ſmoke. B, B, B, are moveable cylinders of earth, each provided with a door D, D, D. In Boerhaave's chemiſtry theſe doors are repreſented as having iron hinges and latchets; but they may be formed to more advantage of ſquare pieces of earth, having two holes in the middle, by which they may be occaſionally taken out, by introducing an iron fork. In like manner, the domes and cylinders,

Chemical Furnaces. cylinders, in Boerhaave's chemiſtry, are repreſented with iron handles; but they may be almoſt as eaſily taken off by the cheaper contrivance of having four holes in each, two directly oppoſite to one another, into which two ſhort forks may be introduced when the parts are to be ſeparated.

In the lowermoſt cylinder is to be placed an iron-grate, a little below the door, for ſupporting the fire. In the under part is a ſmall hole, big enough for introducing the pipe of a pair of good perpetual bellows when the fire is to be violently excited. Dr Lewis prefers the organ-bellows to any other kind.

When the bellows is uſed, the whole muſt ſtand upon a cloſe cylinder A, that the air may be confined, and made to paſs through the fuel. By having more bellows, the fire may be excited to a moſt intenſe degree. In this caſe, the pipe of every one of them muſt enter the cylinder B.

Each of the cylinders ſhould have, in its upper part a round hole, oppoſite to its door, for carrying off the ſmoke, by means of a pipe inſerted into it, when the furnace is uſed for diſtillations by the ſand-bath. Each cylinder ought likewiſe to have a ſemicircular cut in the oppoſite ſides, both above and below, that when the under cut of the upper cylinder is brought directly above the upper cut of the lower one, a perfect circle may be formed. Theſe are for giving a paſſage to the necks of retorts, when diſtillation by the retort is to be performed. The holes may be occaſionally filled with ſtopples made of the ſame materials with the body of the furnace.

The moſt convenient ſituation for a furnace of this kind would be under a chimney, the vent of which might be eaſily ſtopped up by a broad plate of iron, in which a hole ought to be cut for the reception of the earthen tube of the dome. By this means the uſe of a long tube, which at any rate muſt be very troubleſome, might be eaſily avoided, and a very ſtrong blaſt of air would paſs through the fuel. If it is found convenient to place the furnace at ſome diſtance from the chimney, a plate-iron pipe muſt be procured to fit the earthen pipe of the dome, and carry the ſmoke into the chimney. This pipe will alſo be of uſe, when the furnace is uſed for diſtillations by the ſand-bath; it muſt then be inſerted into the hole oppoſite to the door of any of the cylinders, and will convey away the ſmoke, while the mouth of the cylinder is totally covered with a ſand-pot.

601 Dr Lewis's portable furnaces.

For portable furnaces, Dr Lewis greatly recommends the large black crucibles, marked n° 60, on account of their reſiſting a violent heat, and being very eaſily cut by a knife or ſaw, ſo that doors, &c. may be formed in them at pleaſure. The bottom of one of theſe large ones being cut out, a grate is to be put into the narrow part of it. For grates, the doctor recommends caſt iron-rings, having each three knobs around them. Theſe knobs go into correſponding cavities of the outer rings, and the knobs of the outermoſt reſt on the crucible, which is to be indented a little to receive them, that ſo the grate may reſt the more firmly, and the furnace not be endangered from the ſwelling of the iron by heat. When this is to be made uſe of as a melting-furnace, and a violent heat to be excited, another crucible muſt be inverted on that which contains the fuel, which ſerves inſtead of the dome of the laſt mentioned furnace: and as whatever is ſaid of it muſt likewiſe be applicable to the two crucibles when placed above one another, we need give no farther deſcription of the doctor's portable furnace.

602 Objection to their uſe in ſome caſes.

No doubt, the great experience of Dr Lewis, in chemical matters muſt give very conſiderable weight to any thing he advances; and the warmth with which he recommends the furnaces muſt convince us, that he has found them abundantly anſwer the purpoſes of experiments. We cannot help thinking, however, that where a very great and laſting heat is to be given, the thickneſs, and even the *form*, of theſe crucibles, is ſome objection to their uſe. It is certain that ſuch a permanent, or, as the workmen call it, a *ſolid* heat, can never be given where the walls of a furnace are thin, as when they are of ſufficient thickneſs. They are alſo very apt to burſt with great heat; and, for this reaſon, Dr Lewis deſires his furnace to be ſtrengthened with copper hoops. This diſpoſition to burſt proceeds from the inner parts which are more intenſely heated than the outer, expanding more than theſe do, and conſequently burſting them. Hence the doctor deſires his furnace to be ſtrengthened alſo by putting it within another crucible of a larger ſize, and the intermediate ſpace to be filled up with a mixture of ſifted aſhes and water. For moſt chemical proceſſes, where only a ſmall degree of heat is requiſite, theſe furnaces anſwer beyond any thing that has hitherto been attempted. The whole is to be ſupported by an iron ring with three feet

2d 602 Dr Black's furnace deſcribed. Plate CXXXIII fig. 5, 8, 9.

Dr Black has contrived a furnace in which all theſe inconveniences are avoided. Two thick iron plates, above and below, are joined by a thinner plate, forming the body of the furnace, which is of an oval form. The upper part is perforated with two holes; the one A, pretty large, which is the mouth of the furnace, and which is of a circular form: the other behind it, B, of an oval form, and deſigned for faſtening the end of the vent which is ſcrewed down upon it. The undermoſt thick plate has only the large circular opening G near to the middle, but not altogether ſo, being nearer to one ſide of the ellipſe than the other, where the round hole in the top is placed; ſo that a line paſſing this circular hole has a little obliquity forwards. The aſh-pit C E is likewiſe made of a nelliptical form, and a very ſmall matter widened; ſo that the bottom of the furnace is received within the ellipſe. A little below, there is a border D that receives the bottom of the furnace; and except the holes of the damping-plate E, the parts are all cloſed by means of ſoft lute, upon which the body of the furnace is preſſed down; by which means the joining of the two parts, and of all the different pieces, are made quite tight; for the body, fire place, aſh-pit, vent, and grate, are all ſeparable from one another. As the furnace comes from the workman, the grate is made to apply to the outſide of the lower part. It conſiſts of a ring laid on its edge, and then bars likewiſe laid on their edges; and from the outer ring proceed four pieces of iron, by means of which it may be ſcrewed down; ſo it is kept out of the cavity of the furnace, and preſerved from the extremity of the heat. Thus it laſts much longer, and indeed hardly liable to any decay; for by being expoſed to the cool air, it is kept ſo cool, that it is

Chemical Furnaces.

is never hurt by the heat of the fuel. The sides, which are made of plate iron must be luted within, to confine the heat, and preserve them from its action.

603 How adapted to the various operations of chemistry.

To adapt this to the various operations of chemistry, we may observe, that for a melting furnace it is very convenient; we need only provide a cover for the opening above, which is made the door; and which being immediately over the grate, is convenient for introducing the substances to be acted upon, and for allowing us to look into the vessel and take it out. This cover may be a piece of tile, or two bricks rendered flat and square. Dr Black commonly uses a kind of lid with a rim containing a quantity of lute; and to augment the heat, we may increase the height of the vent. It can be employed in most operations in the way of essaying; and the situation of the door allows us to see the substances very readily. It does not admit the introduction of the muffle; but can be employed in all those operations where the muffle is made use of; and in Cornwall in England such a furnace is made use of for essaying of metals. To preserve the substance from the contact of the fuel, they cut off about a third part of the length of a brick, and then put it on one end on the middle of the grate. They choose their fuel of large pieces, that the air may have free passage through it, and open a little of the door, which occasions a stream of air to flow in; and this strikes upon the substance and produces the effect desired; so that it may be used in the calcination of lead to convert it into litharge. It also answers very well in operations for producing vapour. If we desire to employ it in distillations which require an intense heat, the earthen retort is to be suspended by means of an iron ring having three branches standing up from it, and which hangs down about half a foot from the hole; so that the bottom of the retort rests upon the ring, and is immediately hung over the fuel: and the opening between the mouth of the furnace and retort is filled up with broken crucibles and potsherds, which are covered over with ashes that transmit the heat very slowly; so it answers for distillations performed with the naked fire. Dr Black has sometimes caused them be provided with a hole in the side, from which the neck of the retort may be made to come out; and in this way has distilled the phosphorus of urine, which requires a very strong heat. For distillations with retorts performed with the sand-bath, there is an iron pot fitted for the opening of the furnace, which is set on and employed as a sand-pot. The vent of the furnace then becomes the door; and it answers very well for that purpose; and is more easily kept tight than if it were in the side, and may be kept close with a lid of charcoal and clay. In like manner it answers well for the common still, which may be adapted to it; part of it being made to enter the open part of the furnace, and hang over the fire, as in Plate CXXXIII. fig. 8. and 9. that the bottom part of that still may be made to enter; and the vent becomes the door, by which fresh fuel may be added. Indeed it is seldom necessary to add fresh fuel during any operation. In the ordinary distillations it is never necessary; and even in distilling mercury, phosphorus, &c. it generally contains enough to finish the operation; so effectually is the heat preserved from loss or dissipation, and so very slow is the consumption of the fuel.

604 Luting proper for his furnace.

For luting this and other furnaces, the doctor finds nothing preferable to a simple mixture of sand and clay. The proportions for standing the violence of fire are four parts of sand to one of clay; but when designed for the lining of furnaces, he uses six or seven of sand to one of clay, the more effectually to prevent the contraction of the latter; for it is known from experiments, that clay, when exposed to a strong heat, contracts the more in proportion to its purity. The sand settles into less bulk when wet, and does not contract by heat, which it also resists as well as the clay itself.

Besides this outside lining next the fire, Dr Black uses another to be laid on next the iron of the furnace; and this consists of clay mixed with a large portion of of charcoal dust. It is more fit for containing the heat, and is put next to the iron, to the thickness of an inch and a half. That it may be pretty dry when 605 Method of applying the lute.
first put in, he takes three parts by weight of the charcoal dust, and one of the common clay, which must be mixed together when in dry powder, otherwise it is very difficult to mix them perfectly. As much water is added as will form the matter into balls; and these are beat very firm and compact by means of a hammer upon the inside of the furnace. The other lute is then spread over it to the thickness of about half an inch, and this is also beat solid by hammering; after which it is allowed to dry slowly, that all cracks and fissures may be avoided: and after the body of the furnace is thus lined, the vent is screwed on and lined in the same manner. It must then be allowed to dry for a long time; after which a fire may be kindled, and the furnace gradually heated for a day or two. The fire is then to be raised to the greatest intensity; and thus the luting acquires a hardness equal to that of free-stone, and is afterwards as lasting as any part of the furnace. 2d 605 Melting furnace.

When furnaces are used in the large way, they are always built of brick, and each particular operation has a furnace allotted for itself. The melting-furnace, where very large quantities of matter are not to be melted at once, requires only to be built of brick in such a form as we have already described; only, as it would perhaps be troublesome to procure a dome of the proper figure, the forepart of it may be left entirely open for the admission of melting vessels. The opening may be closed up with bricks and earth during the operation. There is no necessity for having the inside of a circular form; a square one will answer the purpose equally well. According to the author of the Chemical Dictionary, when the internal diameter D C of such a furnace is 12 or 15 inches, the diameter of the tube G I 8 or 9 inches, and its height 18 or 20 feet, and when the surface is well supplied with fuel, and extreme heat is produced; in less than an hour the furnace will be white and dazzling like the sun; its heat will be equal to the strongest glass-house furnace; and in less than two hours will be melted whatever is fusible in furnaces. The hottest part is at H F, 4 or 6 inches above the grate. A plate-iron tube may be advantageously supplied by a short chimney of bricks, built under a pretty high vent, so as the whole may easily be stopped, except that passage which transmits the smoke of the furnace. By this means a very strong current of air will be made to pass through the fuel.

Plate CXXXIV. fig. 2.

606 Mr Pott's melting furnace described.

On this subject Dr Black informs us, that Mr Pott of Berlin employs one almost similar to the above, for

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for making experiments on earthen ware; by which he showed that many substances formerly reckoned infusible, might nevertheless be melted by fire raised to a very intense degree; and that several of these bodies, when mixed together, form compounds which may be melted without any difficulty. From this a tube arises to some height, and there is an additional tube which may be put on to the height of above 10 feet. The fire-place is narrow below, but widens towards the middle, and contracts again at top, for the sake of the vessels which are put into it, and which are wider at top than at bottom. Thus the vessel is equally heated, and there is room above for containing a quantity of fuel, which descends as fast as it is consumed. Different reasons have been assigned for this form: thus Dr Boerhaave imagines that the melting furnace should be made of a parabolic form, and Macquer, that it should be in the form of an ellipse; and that the crucible should be placed in one of the foci, where they imagined the heat would be concentrated; but it is very plain, that the materials are such as are not capable of reflecting the rays of heat in a regular manner; and even though they could do so, it would be to no purpose, because the heat and light do not come from any single point, but from a great number, striking the furnace in all possible directions, and which must consequently be reflected in directions as numerous. The furnace is made of iron lined with clay; and as it is difficult to beat out the iron into this roundish form, it may as well be made cylindrical; and it is easy to give the inside what form we please by means of a luting of clay; neither need the dome have the roundish form, but may be simply made conical. The vent should be made about two-thirds of the diameter of the furnace, or such as will give an area of about one-half the grate. A small portable furnace of this kind is very convenient for ordinary crucibles; the largest of which are only about four or five inches high; the widest part of the furnace may be beat out about 10 inches diameter; and when made of thin plate iron, and lined within, are very convenient, and may be heated at very little expence of fuel. But for heating much larger vessels, it is proper to construct them of brick, when they have pretty much the same form; only it is necessary to make them square, and round on the inside with a luting of sand and clay. The top is generally made flat, and covered over with two or three bricks; the vent goes a little backwards, and then is raised to a proper height. Where the vessel to be heated is very large, it is common to leave the front open for putting in the vessel; and then to build it up with bricks, clay, and sand; which can be easily pulled down again when the operation is over.

607 Reasons for making the fire-place of a roundish form.

608 When bellows are necessary.

There are some cases in which it is necessary to have a rapidity of inflammation even beyond what this furnace can give; and in these we have recourse to bellows of various constructions, by which the air can be compressed and made to enter the fuel with great velocity. These again are sometimes wrought by water; but there is another machine which produces a greater effect, viz. the *water-blast* described by Lewis in his *Commercium Philosoph. Technicum.*

609 In what cases the eolipile may be made use of.

The eolipile too may be employed for driving air into fuel. The effect of this has been considered as a proof that air acts by its elasticity in animating fuel, as an elastic fluid vapour from the eolipile produces, the same effect. But when we contrive to send steam instead of air, the same effect is not produced; and the true manner in which this instrument increases the inflammation is by driving air through the fuel: the steam from the vessel spreading and mixing with the air, and driving it before it, makes it strike upon the fuel.

Chemists have generally believed that a wide and high ash-hole greatly increases the power of a melting furnace; but this advantage is found to be merely imaginary, as well as that of introducing the air through a long tube to the ash-hole; unless where the furnace is placed in a close room, so that it is necessary to furnish a greater blast of air than can otherwise have access.

For the form of the furnaces necessary in essaying and smelting of ores or making glass, see ESSAYING GLASS, and SMELTING. 610

Stills, sand-pots &c. how to set.

When large stills, sand-pots, &c. are to be fixed with a view to daily use, it is a matter of no small consequence to have them put up in a proper manner. The requisites here are, 1. That the whole force of the fire should be spent on the distilling vessel or sand-pot, except what is necessarily imbibed by the walls of the furnace. 2. That the vessel should be set in such a manner as that they may receive heat even from the furnace walls; for a still which contains any liquid can never be made so hot as a piece of dry brick. 3. It is absolutely necessary that the force of the fire be not allowed to collect itself upon one particular part of the vessel; otherwise that part will soon be destroyed. 3. The draught of air into furnaces of this kind ought to be moderate; only so much as will prevent smoke. If a strong blast of air enters, not only a great part of the heat will be wasted by going up the chimney, but the outside of the vessel will be calcined every time the fire is kindled, and thus must be soon rendered unfit for use.

There are few of the common workmen that are capable of building furnaces properly; and it is very necessary for a chemist to know when they are properly done, and to make the workmen act according to his directions. As the still, or whatever vessel is to be fixed, must have a support from the furnace on which it is built, it is evident the *whole* of its surface cannot be exposed to the fire. For this reason many of these vessels have had only their bottom exposed to the fire, no more space being left for the action of the heat, than the mere circular area of the still bottom; and the fire passing directly through a hole in the back part of the building, which communicated with a chimney, and consequently had a strong draught, scarce spent any of its force on the still, but went furiously up the chimney. By this means an extraordinary waste of fuel was occasioned; and that part of the still-bottom which was next the chimney receiving the whole force of the flame, was soon destroyed. Attempts were made to remedy this inconvenience, by putting the fire something forward, that it might be at greater distance from the chimney, and consequently might not spend its force in the air. This too was found to avail very little. A contrivance was then fallen upon to make the vent pass round the body of the still in a spiral form. This was a considerable improvement; but had the inconvenience of making the fire spend itself uselessly on the walls of the furnace, and besides wasted that part of the still which touched the

Chemical Furnaces.

the under part of the vent. A much better method is to build the back part of the furnace entirely close, and make the fire come out through a long narrow opening before; after which it passes out through a flue in the back and upper part of the furnace into the chimney.

The only convenience of this form is, that the vent must either be very wide, or it is apt to choak up with soot, which last is a very troublesome circumstance. If the vent is made very wide, a prodigious draught of air rushes through the fuel, and increases the heat to such a degree as to calcine the metal of which the still is made; and, on the other hand, nothing can be more disagreeable than to have the vent of a furnace stopped up with soot. These inconveniences, however, are totally avoided by making two small vents, one on each side of the distilling vessel, which may communicate with a chimney by means of two tubes either of plate-iron or formed with clay or bricks, which may be occasionally taken off if they happen to be choaked up. The vessel is to be suspended by three trunnions, so that the whole surface may be exposed to the fire, excepting a ring the thickness of a brick all round; so that a very strong heat will be communicated although the furnace draws but little. The two small vents on each side will draw the flame equally; and by this means the most equable heat can be preserved, and may be pushed so far as to make the whole bottom and sides of the vessel intensely red. Such a construction as this is more especially useful for sand-pots, and those which are used for distilling alkaline spirits from bones.

In the use of the furnaces hitherto described, the attendance of the operator is necessary, both for inspecting the processes, and for supplying and animating the fuel. There are some operations, of a slower kind, that require a gentle heat to be continued for a length of time; which demand little attendance in regard to the operations themselves, and in which, of consequence, it is extremely convenient to have the attendance in regard to the fire as much as possible dispensed with. This end has been answered by the furnace called *athanor*; but the use of it has been found attended with some inconveniences, and it is now gerally laid aside.

611 Lamp furnace.

Sundry attempts have been made for keeping up a continued heat, with as little trouble as in the athanor, by the flame of a lamp; but the common lamp-furnaces have not answered so well as could be wished. The lamps require frequent snuffing, and smoke much; and the soot accumulated on the bottom of the vessel placed over them, is apt, at times, to fall down and put out the flame. The largeness of the wick, the irregular supply of oil from the reservoir by jets, and the oil being suffered to sink considerably in the lamp, so that the upper part of the wick burns to a coal, appeared to be the principal causes of these inconveniences; which accordingly were found to be in great measure remedied by the following construction.

Plate CXXXIV. fig. 8.

The lamp consists of a brass pipe 10 or 12 inches long, and about a quarter of an inch wide, inserted at one end into the reservoir of the oil, and turned up at the other to an elbow, like the bole of a tobacco-pipe, the aperture of which is extended to the width of near two inches. On this aperture is fitted a round plate, having 5, 6, or 7 small holes, at equal distances, round its outer part, into which are inserted as many pipes about an inch long: into these pipes are drawn threads of cotten, all together not exceeding what in the common lamps form one wick: by this division of the wick, the flame exposes a larger surface to the action of the air, the fuliginous matter is consumed and carried off, and the lamp burns clear and vivid.

The reservoir is a cylindric vessel, eight or ten inches wide, composed of three parts, with a cover on the top. The middle partition communicates, by the lateral pipe, with the wicks; and has an upright open pipe soldered into its bottom, whose top reaches as high as the level of the wick; so that, when this part is charged with oil, till the oil rises up to the wicks in the other end of the lamp, any further addition of oil will run down through the upright pipe into the lower division of the reservoir. The upper division is designed for supplying oil to the middle one; and, for that purpose, is furnished with a cock in the bottom, which is turned more or less, by a key on the outside, that the oil may drop fast enough to supply the consumption, or rather faster, for the overplus is of no inconvenience, being carried off by the upright pipe; so that the oil is always, by this means, kept exactly at the same height in the lamp. For common uses, the middle division alone may be made to suffice; for, on account of its width, the sinking of the oil will not be considerable in several hours burning. In either case, however, it is expedient to renew the wicks every two or three days; oftener or seldomer according as the oil is more or less foul; for its impure matter, gradually left in the wicks, occasions the flame to become more and more dull. For the more convenient renewing of them, there should be two of the perforated plates; that when one is removed, another, with wicks fitted to it, may be ready to supply its place.

One of the black-lead pots, recommended by Dr Lewis for his portable furnace, makes a proper furnace for the lamp. If one is to be fitted up on purpose for this use, it requires no other aperture than one in the bottom for admitting air, and one in the side for the introduction of the elbow of the lamp. The reservoir stands on any convenient support without the furnace. The stopper of the side aperture consists of two pieces, that it may be conveniently put in after the lamp is introduced; and has a round hole at its bottom fitting the pipe of the lamp. By these means, the furnace being set upon a trevet or open foot, the air enters only underneath, and spreads equally all around, without coming in streams, whence the flame burns steady. It is not adviseable to attempt raising the heat higher than about the 450th degree of Fahrenheit's thermometer; a heat somewhat more than sufficient for keeping tin in perfect fusion. Some have proposed giving a much greater degree of heat in lamp-furnaces, by using a number of large wicks; but when the furnace is so heated the oil emits copious fumes, and its whole quantity takes fire. The balneum or other vessel including the subject-matters, is supported over the flame by an iron ring, as already described in the sand-bath and still: a bath is here particularly necessary, as the subject would otherwise be very unequally heated, only a small part of the vessel being exposed to the flame. Since the new invention of Argand's lamps, which perfectly consume the oil, attempts have been made to construct

Chemical Furnaces.

construct lamp-furnaces on their principles; though, on the whole, it is to be doubted whether they are preferable to the above construction or not.

Explanations of the Plates.

Plate CXXXIII. fig. 1. shows the figure of the still recommended by Dr Black; the bottom formed in such a manner as to go into his furnace. A, the body; B, the head; C C, the tube conveying the steam into the worm; D F, the figure of the worm; E, the worm-tub.

Fig. 2. A head taller than the common, proper for rectifying ardent spirits.

Fig. 3. Another kind of still for a common furnace, having a concave bottom for receiving the flame. A, the body; B, the head.

Fig. 4. Papin's digester. See CHEMISTRY. n° 567. A, the body; B B, the cross-bars; C D, the screw; E, the lid.

Fig. 5. The outer case of Dr Black's furnace without the luting. A, the body; B, the feet; I G, the opening at top.

Fig. 6. C, the grate of the same, with four projections, having holes in them to fasten it by nails to the inside of the furnace.

Fig. 7. A crooked funnel for putting matters into a retort without touching the sides or neck.

Fig. 8. Dr Black's furnace put together in readiness for chemical operations. A the mouth; B, the chimney; C, the door of the ash-hole. E, the registers for admitting air.

Fig. 9. A section of the same, showing its inside structure. F, the top-cover; G, the body, with part of the grate; D, the receptacle for the ashes; C, its door; E, the registers.

Fig. 10. An iron support for a crucible.

Fig. 11. The figure of a crucible.

Plate CXXXIV. fig. 1. Dr Boerhaave's portable furnace. See CHEMISTRY, n° 600.

Fig. 2. Macquer's melting-furnace. AA, the door of the ash-pit; B, the space betwixt the top of the ash-pit and fire-place; D C, the bars; G H E F, the fire-place; I, the funnel. *Ibid.* 2d n° 605.

Fig. 3. Dr Lewis's portable furnace fitted with a still, *Ibid.* n° 601, 602.

Fig. 4. Shows the figure of retorts of different kinds. A, the body; B, the neck.

Fig. 5. A matrass and alembic head, with a cucurbit and alembic head made of one piece. A, the body; B, the long neck of the matrass; C, the alembic head. A, the body of the cucurbit; B, the head; C, an opening in the head for putting in the matter to be distilled; D, a glass stopple fitted to the opening just mentioned; E, the opening of the cucurbit mouth.

Fig. 6. The pelican and cucurbit now in disuse. A, the body of the pelican; B, the head; C, an opening fitted with a stopple; D D, the arms. A, the body of the cucurbit; B, the head; C, the neck; D, the spout.

Fig. 7. A row of adopters or aludels.

Fig. 8. Dr Lewis's lamp-furnace. *Ibid.* n° 611.

PART II. PRACTICE.

SECT. I. *Salts.*

§ 1. *Of the* VITRIOLIC *Acid, and its Combinations.*

612 Never found pure.

THE vitriolic acid is never found pure, but always united with some proportion, either of phlogiston or metallic and earthy substances. Indeed there is scarce any kind of earth which does not contain some portion of this acid, and from which it may always some way or other be separable. When pure, the vitriolic acid appears in the form of a transparent colourless liquor. By distilling in a glass retort, the aqueous part arises, and the liquor which is left becomes gradually more and more acid. This operation is generally called the *rectification*, or *dephlegmation*, of the acid. After the distillation has gone on for some time, the water adheres more strongly to what remains in the retort, and cannot be forced over without elevating part of the acid along with it. The remaining acid, being also exceedingly concentrated, begins to lose its fluidity, and puts on the appearance of a clear oil. This is the state in which it is usually sold, and then goes by the name of *oil of vitriol*. If the distillation is still farther continued, with a heat below 600° of Fahrenheit's thermometer, the acid gradually loses more and more of its fluidity, till at last it congeals in the cold, and becomes like ice. In this state it is called the *icy oil of vitriol*. Such exceedingly great concentration, however, is only practised on this acid for curiosity. If the heat be suddenly raised to 600°, the whole of the acid rises, and generally cracks the receiver. Clear oil of vitriol is immediately turned black by an admixture of the smallest portion of inflammable matter.

613 Rectification.

614 Attracts moisture from the air.

The icy oil of vitriol, and even that commonly sold, attracts the moisture of the air with very great force. Newmann relates, that having exposed an ounce of this acid to the air, from September 1736 to September 1737, at the end of the twelvemonth it weighed seven ounces and two drachms; and thus had attracted from the air above six times its own weight of moisture. This quantity, however, seems extraordinary; and it is probable, that in so long a time some water had been accidentally mixed with it; for Dr Gould, professor at Oxford, who seems to have tried this matter fully, relates, that three drachms of oil of vitriol acquired, in 57 days, an increase only of six drachms and an half. The acid was exposed in a glass of three inches diameter; the increase of weight the first day was upwards of one drachm; in the following days less and less, till, on the fifty-sixth, it scarce amounted to half a grain. The liquor, when saturated with humidity, retained or lost part of its acquired weight according as the atmosphere was in a moist or dry state; and this difference was so sensible as to afford an accurate hygrometer. Hoffman having exposed an ounce and two scruples in an open glass-dish, it gained seven drachms and a scruple in 14 days.

615 Productive both of cold and heat.

This acid, when mixed with a large quantity of water, makes the temperature something colder than before; but if the acid bears any considerable proportion to the water, a great heat is produced, so as to make the vessel insupportable to the hand; and therefore

Vitriolic acid and its combinations.

fore such mixtures ought very cautiously, or rather not at all, to be made in glass vessels, but in the common stone-bottles, or leaden vessels, which are not apt to be corroded by this acid. The greatest heat is produced by equal parts of acid and water.

616
Quantity of alkali saturated by it.

Though the vitriolic acid unites itself very strongly with alkalies, both fixed and volatile, it does not saturate near so much of the latter as of the former. A pound of oil of vitriol will saturate two of the common fixed alkali, but scarce one of volatile alkali. The specific gravity of good oil of vitriol is to water as 17 to 8.

617
Effects on the human body.

If the concentrated acid is applied slightly and superficially to the skin of a living animal, it raises a violent burning heat and pain; but a larger quantity pressed on, so as to prevent the ingress of aerial moisture, occasions little pain or erosion. If diluted with a little water, it proves corrosive in either case. Largely diluted with water, this acid is employed medicinally for checking putrefaction, abating heat, and quenching thirst; in debilities of the stomach, and heartburn. To persons of weak and unsound lungs, to women who give suck, to hydropic or emaciated persons, it is injurious. Some recommend it as a collyrium for sore eyes; but as it coagulates the animal juices, corroding and indurating the solids, it seems very unfit for being applied to that tender organ.

618
Difficulty of procuring it by itself.

The vitriolic acid is so much used in different arts and manufactures, that the making of it has become a trade by itself; and the procuring it in plenty, and at a cheap rate, would be a very advantageous piece of knowledge to any person who could put it in practice. This, however, is very far from being easily done; for though it exists in almost every mineral substance, the attraction betwixt this acid and the bases with which it unites, is found to be so strong, that we can only decompose such combinations by presenting another substance to the acid, to which it has a greater attraction than that one wherewith it is joined. Thus the first combination is indeed dissolved, but we have another from which it is eqally difficult to extricate the acid by itself. Thus, if we want to disengage the vitriolic acid from any metallic substance, suppose iron, this may be easily done by throwing a calcareous earth into a solution of green vitriol. We have now a compound of vitriolic acid with the calcareous earth, which is known by the name of *gypsum* or *selenites*. If we want to decompose this we must apply a volatile or or a fixed alkali; and the result of this will constantly be a new combination, which we are as unable to decompose, and indeed more so, than the first. There are two general methods which have been in use for procuring the vitriolic acid in such quantity as to supply the demands of trade. The one is from pyrites, and the other from sulphur.

I. From *Pyrites*, with the making of Copperas, and obtaining the pure Oil of Vitriol from it.

619
Pyrites, where found.

Pyrites are found in large quantity in the coal-mines of England, where most of the copperas is made. They are very hard and heavy substances, having a kind of brassy appearance, as if they contained that metal; and hence they are called *brasses* by the workmen. A very large quantity of these is collected, and spread out upon a bed of stiff clay to the depth of three feet. After being some time exposed to the air, the uppermost ones lose their metallic appearance, split, and fall to powder. The heaps are then turned, the under part uppermost, so as to expose fresh pyrites to the air. When they are all reduced to powder, which generally requires three years, the liquor, which is formed by the rain-water running from such a large mass, becomes very acid, and has likewise a styptic vitriolic taste. It is now conveyed into large cisterns lined with clay, whence it is pumped into a very large flat vessel made of lead. This vessel, which contains about 15 or 20 tons of liquor, is supported by cast-iron plates about an inch thick, between which and the lead a bed of clay is interposed. The whole rests upon narrow arches of brick, under which the fire is placed. Along with the liquor, about half a ton or more of old iron is put into the evaporating vessel. The liquor, which is very far from being saturated with acid, acts upon the iron, and, by repeated filling up as it evaporates, dissolves the whole quantity. By the time this quantity is dissolved, a pellicle is formed on the surface. The fire is then put out; and as such a prodigious quantity of liquor does not admit of filtration, it is left to settle for a whole day, and then is let off by a cock placed a little above the bottom of the evaporating vessel, so as to allow the impurities to remain behind. It is conveyed by wooden spouts to a large leaden cistern, five or six feet deep, sunk in the ground, and which is capable of containing the whole quantity of liquor. Here the copperas crystallizes on the sides, and on sticks put into the liquor. The crystallization usually takes up three weeks. The liquor is then pumped back into the evaporating vessel; more iron, and fresh liquor from the pyrites, are added; and a new solution takes place.

Copperas is used, in dyeing, for procuring a black colour; and is an ingredient in making common ink. It is also used in medicine as a corroborant, under the name of *salt of steel*; but before it is used with this intention, it is redissolved in water, and crystallized, with the addition of a little pure oil of vitriol. Whether it is at all mended by this supposed purification, either in appearance or quality, is very doubtful.

This process furnishes us first with a very impure vitriolic acid, which could not be applied to any useful purpose; afterwards with an imperfect neutral salt, called *green vitriol*, which is applicable to several purposes where the pure acid itself could not be used; but still the acid by itself is not to be had without a very troublesome operation.

620
Distillation of vitriolic acid from copperas.

Though this acid adheres very strongly to iron, it is capable of being expelled from it by fire; yet not without a very violent and long-continued one. If we attempt to distil green vitriol in a retort, it swells and boils in such a manner by the great quantity of water contained in its crystals, that the retort will almost certainly crack; and though it should not, the salt would be changed into an hard stony mass, which the fire could never sufficiently penetrate so as to extricate the acid. It must therefore be calcined previous to the distillation. This is best done in flat iron-pans, set over a moderate fire. The salt undergoes the watery

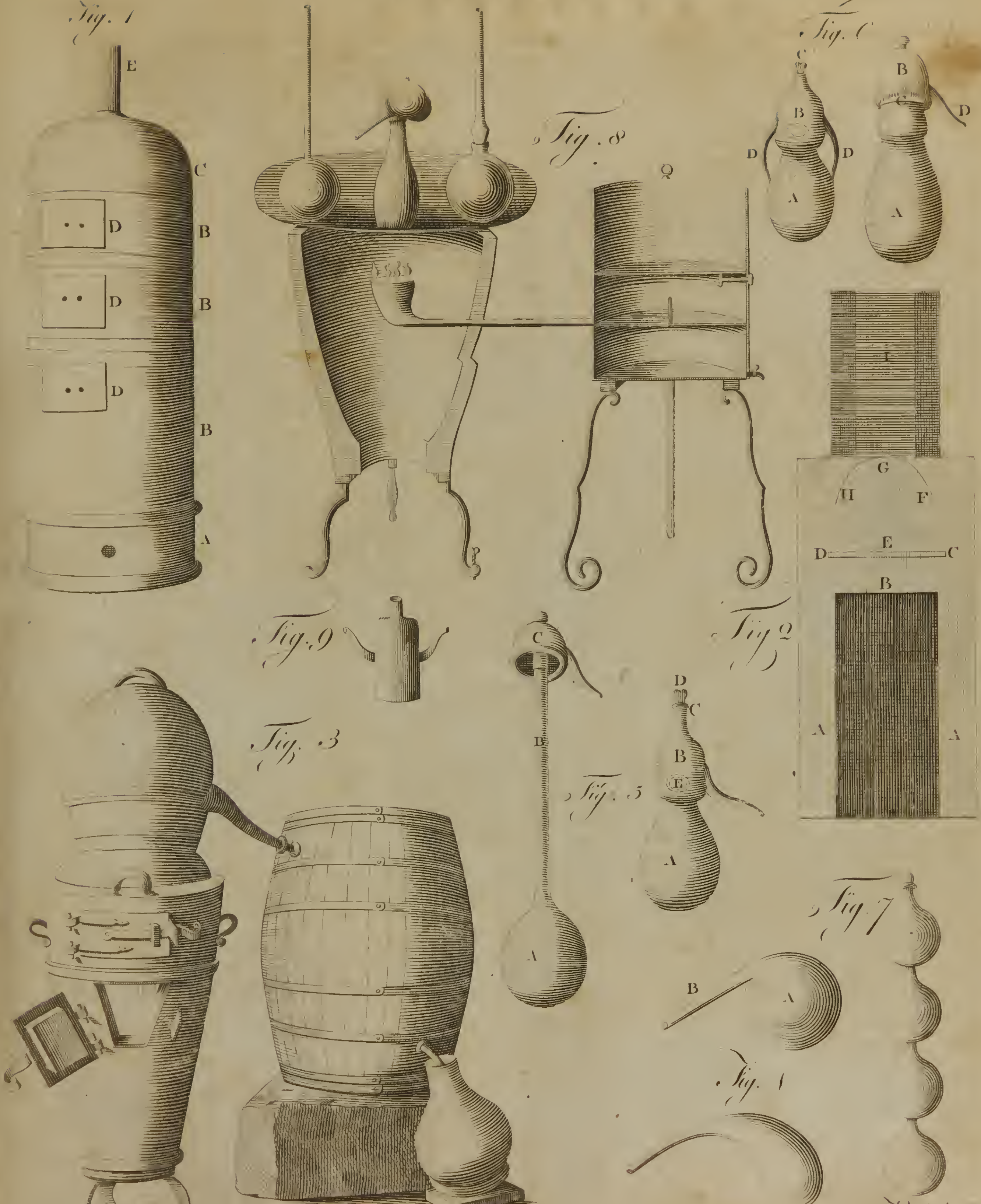
Fig. 1
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Fig. 8
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tery fuſion, (See FUSION); after which it becomes opaque and white. By a continuance of the fire, it becomes brown, yellow, and at laſt red. For the purpoſes of diſtillation, it may be taken out as ſoon as it has recovered its ſolidity.

The dry vitriol, being now reduced to powder, is to be put into an earthen retort, or rather long neck (a kind of retort where the neck iſſues laterally, that the vapours may have little way to aſcend), which it may nearly fill. This retort muſt be placed in a furnace capable of giving a very ſtrong heat, ſuch as the melting furnace we have already deſcribed. A large receiver is to be fitted on; and a ſmall fire made in the furnace to heat the veſſels gradually. White fumes will ſoon come over into the receiver, which will make the upper part warm. The fire is to be kept of an equal degree of ſtrength, till the fumes begin to diſappear, and the receiver grows cool. It is then to be increaſed by degrees; and the acid will become gradually more and more difficult to be raiſed, till at laſt it requires an extreme red, or even white, heat. When nothing more will come over, the fire muſt be ſuffered to go out, the receiver be unluted, and its contents poured into a bottle fixed with a glaſs ſtopper. A ſulphureous and ſuffocating fume will come from the liquor, which muſt be carefully avoided.

621 Preſervatives of wood.

In the retort, a fine red powder will remain, which is uſed in painting, and is called *colcothar of vitriol.* It is uſeful on account of its durability; and, when mixed with tar, has been employed as a preſervative of wood from rotting; but Dr Lewis prefers finely powdered pit-coal. As a preſervative for maſts of ſhips, he recommends a mixture of tar and lampblack; concerning which he relates the following anecdote.

"I have been favoured by a gentleman on board of a veſſel in the Eaſt-Indies, with an account of a violent thunder-ſtorm, by which the main-maſt was greatly damaged, and whoſe effects on the different parts of the maſt were pretty remarkable. All the parts which were greaſed or covered with turpentine were burſt in pieces: thoſe above, between, and below the greaſed parts, as alſo the yard-arms, the round-top or ſcaffolding, coated with tar and lamp-black, remained unhurt."

622 Rectification.

Oil of vitriol, when diſtilled in this manner, is always of a black colour, and muſt therefore be rectified by diſtillation in a glaſs retort. When the acid has attained a proper degree of ſtrength, the blackneſs either flies off, or ſeparates and falls to the bottom, and the liquor becomes clear. The diſtillation is then to be diſcontinued, and the clear acid which is left in the retort kept for uſe.

This was the firſt method by which the vitriolic acid was obtained; and from its being diſtilled from vitriol has ever ſince retained the name of *oil of vitriol.* Green vitriol is the only ſubſtance from which it is practicable to draw this acid by diſtillation; when combined with calcareous earths, or even copper (though to this laſt it has a weaker attraction than to iron), it reſiſts the fire moſt obſtinately. When diſtillation from vitriol was practiſed, large furnaces were erected for that purpoſe, capable of containing an hundred long necks at once: but as it has been diſcovered to be more eaſily procurable from ſulphur, this method has been laid aſide, and it is now needleſs to deſcribe theſe furnaces.

II. To procure the Vitriolic Acid from *Sulphur.*

623 Quantity of acid in ſulphur.

This ſubſtance contains the vitriolic acid in ſuch plenty, that every pound of ſulphur, according to Mr Kirwan's calculation, contains more than one-half of pure acid; which being in a ſtate perfectly dry, is conſequently of a ſtrength far beyond that of the moſt highly rectified oil of vitriol. Common oil of vitriol requires to be diſtilled to one-fourth of its quantity before it will coagulate when cold; and even in this ſtate it undoubtedly contains ſome water. No method, however, has as yet been fallen upon to condenſe all the ſteams of burning ſulphur, at leaſt in the large way, nor is any other profitable way of decompoſing ſulphur known than that by burning; and in this way the moſt ſucceſsful operators have never obtained more than 14 ounces of oil from a pound of ſulphur.

624 Quantity produced from it.

625 Methods of obviating the difficulties in this proceſs.

The difficulties here are, that ſulphur cannot be burnt but in an open veſſel; and the ſtream of air, which is admitted to make it burn, alſo carries off the acid which is emitted in the form of ſmoke. To avoid this, a method was contrived of burning ſulphur in large glaſs globes, capable of containing an hogſhead or more. The fume of the burning ſulphur was then allowed to circulate till it condenſed into an acid liquor. A greater difficulty, however, occurs here; for though the ſulphur burns very well, its ſteams will never condenſe. It has been ſaid, that the condenſation is promoted by keeping ſome warm water continually ſmoking in the bottom of the globe; and even Dr Lewis has aſſerted this: but the ſteam of warm water immediately extinguiſhes ſulphur, as we have often experienced; neither does the fume of burning ſulphur ſeem at all inclinable to join with water, even when forced into contact with it. As it ariſes from the ſulphur, it contains a quantity of phlogiſton, which in a great meaſure keeps it from uniting with water; and the deſideratum is not ſomething to make the ſulphur burn freely, but to deprive the fumes of the phlogiſton they contain, and render them miſcible with water. For this purpoſe nitre has been advantageouſly uſed. This conſumes a very large quantity of the phlogiſton contained in ſulphur, and renders the acid eaſily condenſible: but it is plain that few of the fumes, comparatively ſpeaking, are thus deprived of the inflammable principle; for the veſſel in which the ſulphur and nitre are burnt, remains filled with a volatile and moſt ſuffocating fume, which extinguiſhes flame, and iſſues in ſuch quantity as to render it highly dangerous to ſtay near the place. It has been thought that nitre contributes to the burning of the ſulphur in cloſe veſſels; but this too is a miſtake. More ſulphur may be burnt in an oil of vitriol globe without nitre than with it, as we have often experienced; for the acid of the ſulphur unites with the alkaline baſis of the nitre, and forms therewith an uninflammable compound, which ſoon extinguiſhes the flame, and even prevents a part of the ſulphur from being burnt either at that time or any other.

626 Effervescence between the nitrous and ſulphureous fumes.

In the condenſation of the fumes of ſulphur by means of nitre, a remarkable efferveſcence happens, which naturally leads us to think that the condenſation is produced by ſome ſtruggle between the vitriolic and nitrous

Vitriolic acid and its combinations.

nitrous acids.—Dr Lewis is of opinion, that the acid thus obtained is perfectly free from an admixture of the nitrous acid: but in this he is certainly miſtaken; for, on rectifying the acid produced by ſulphur and nitre, the firſt fumes that come over are red, after which they change their colour to white. How the nitrous acid ſhould exiſt in the liquor, indeed, does not appear; for this acid is totally deſtructible by deflagration with charcoal: but it does not follow, that becauſe the nitrous acid is deſtroyed when deflagrated with charcoal, it muſt likewiſe be ſo if deflagrated with ſulphur. Indeed it certainly is not; for the clyſſus of nitre made with ſulphur is very different from that made with charcoal.

The proportions of nitre to the ſulphur, uſed in the large oil of vitriol works, are not known, every thing being kept as ſecret as poſſible by the proprietors. Dr Lewis reckons about ſix pounds of nitre to an hundred weight of ſulphur; but from ſuch experiments as we have made, this appears by far too little. An ounce and an half, or two ounces, may be advantageouſly uſed to a pound of ſulphur. In greater proportions, nitre ſeems prejudicial.

627 Lead veſſels, an improvement.

A very great improvement in the apparatus for making oil of vitriol, lies in the uſing lead veſſels inſtead of glaſs globes. The globes are ſo apt to be broken by accident, or by the action of the acid upon them, that common prudence would ſuggeſt the uſe of lead to thoſe who intend to prepare any quantity of vitriolic acid, as it is known to have ſo little effect upon the metal. The leaden veſſels, according to the beſt accounts we have been able to procure, are cubes of about three feet, having on one ſide a door about ſix inches wide. The mixture of ſulphur and nitre is placed in the hollow of the cube, in an earthen ſaucer, ſet on a ſtand made of the ſame materials. The quantity which can be conſumed at once in ſuch a veſſel is about two ounces. To prevent the remains from ſticking to the ſaucer, it is laid on a ſquare bit of brown paper. The ſulphur being kindled, the door is to be cloſe ſhut, and the whole let alone for two hours. In that time the fumes will be condenſed. The door is then to be opened; and the operator muſt immediately retire, to eſcape the ſuffocating fumes which iſſue from the veſſel. It will be an hour before he can ſafely return, and introduce another quantity of materials, which are to be treated preciſely in the ſame manner.

Where oil of vitriol is made in large quantities, the ſlowneſs of the operation requires a great number of globes, and conſtant attendance day and night. Hence the making of this acid is very expenſive: The apparatus for a large work uſually coſts L.1500. ſterling.

Vitriolic Acid combined,

628 Vitriolated tartar.

I. *With Fixed Alkali.* Dilute a pound of oil of vitriol with ten times its quantity of water; diſſolve alſo two pounds of fixed alkaline ſalt in ten pounds of water, and filter the ſolution. Drop the alkali into the acid as long as any efferveſcence ariſes; managing matters ſo that the acid may prevail. The liquor will now be a ſolution of the neutral ſalt, called *vitriolated tartar*, which may be procured in a dry form, either by exſiccation or cryſtallization. In caſe the latter method is made uſe of, ſome more alkali muſt be added when it is ſet to evaporate, for this ſalt cryſtallizes beſt in an alkaline liquor.

Other methods, beſides that above deſcribed, have been recommended for preparing vitriolated tartar; particularly that of uſing green vitriol inſtead of the pure vitriolic acid. In this caſe the vitriol is decompoſed by the fixed alkali: but as the alkali itſelf diſſolves the calx of iron after it is precipitated, it is next to impoſſible to procure a pure ſalt by ſuch a proceſs; neither is there occaſion to be ſolicitous about the preparation of this ſalt by itſelf, as the materials for it are left in greater quantity than will ever be demanded, after the diſtillation of ſpirit of nitre. 629 [630] Different methods of preparing vitriolated tartar.

631 Uſes.

Vitriolated tartar is employed in medicine as a purgative; but is not at all ſuperior to other ſalts which are more eaſily prepared in a cryſtalline form. It is very difficultly ſoluble in water, from which proceeds the difficulty of cryſtallizing it: for if the acid and alkali are not very much diluted, the ſalt will be precipitated in powder, during the time of ſaturation.—It is very difficult of fuſion, requiring a ſtrong red heat; but, notwithſtanding its fixedneſs in a violent fire, it ariſes with the ſteam of boiling water in ſuch a manner as to be almoſt totally diſſipated along with it by ſtrong boiling.—This ſalt has been uſed in making glaſs; but with little ſucceſs, as the glaſs wherein it is an ingredient always proves very brittle and apt to crack of itſelf.

632 Glauber's ſalt.

If, inſtead of the vegetable fixed alkali, the vitriolic acid is ſaturated with the foſſile one called the *ſalt of Soda*, a kind of neutral ſalt will be produced, having very different properties from the vitriolated tartar. This compound is called *Glauber's ſalt*. It diſſolves eaſily in water, ſhoots into long and beautiful cryſtals, which contain a large quantity of water, in conſequence of which they undergo the aqueous fuſion when expoſed to heat. They are alſo more eaſily fuſible than vitriolated tartar.—This kind of ſalt was formerly much recommended as a purgative, and from its manifold virtues was intitled by its inventor *ſal mirabile*. It is, however, found to poſſeſs no virtue different from that of other purgative ſalts: and its uſe is, in many places, entirely ſuperſeded by a ſalt prepared from the *bittern*, or liquor which remains after the cryſtallization of ſea-ſalt, which ſhall be afterwards deſcribed.

633 Glauber's ſecret ſalt ammoniac.

II. *With volatile alkali.* Take any quantity of volatile alkaline ſpirit; that prepared with quicklime is perferable to the other, on account of its raiſing no efferveſcence. Drop into this liquor, contained in a bottle, diluted oil of vitriol, ſhaking the bottle after every addition. The ſaturation is known to be complete by the volatile ſmell of the alkali being entirely deſtroyed. When this happens, ſome more of the ſpirit muſt be added, that the alkali may predominate a little, becauſe the exceſs will fly off during the evaporation. The liquor, on being filtered and evaporated, will ſhoot into fine fibrous plates like feathers. This ſalt, when newly prepared, has a ſulphureous ſmell, and a penetrating pungent taſte. It readily diſſolves in water, and increaſes the coldneſs of the liquor; on ſtanding for a little time, it begins to ſeparate from the water, and vege-

Vitriolic acid and its combinations. vegetate, or ariſe in eſfloreſcences up the ſides of the glaſs. It eaſily melts in the fire; penetrates the common crucibles; and if ſublimed in glaſs veſſels, which requires a very conſiderable heat, it always becomes acid, however exactly the ſaturation was performed.

This ſalt has been dignified with the names of *Glauber's ſecret ſal ammoniac*, or *philoſophic ſal ammoniac*, from the high opinion which ſome chemiſts have entertained of its activity upon metals: but from Mr Pott's experiments, it appears, that its effects have been greatly exaggerated. It diſſolves or corrodes in ſome degree all thoſe metals which oil of vitriol diſſolves, but has no effect upon thoſe on which that acid does not act by
634 itſelf.

Properties of the ſalts. Gold is not touched in the leaſt, either by the ſalt in fuſion, or by a ſolution of it: the ſalt added to a ſolution of gold in aqua-regia occaſions no precipitation or change of colour. On melting the ſalts with inflammable matters, it forms a ſulphureous compound, which diſſolves gold in fuſion, in the ſame manner as compoſitions of ſulphur and fixed alkaline ſalt. Melted with ſilver, it corrodes it into a white calx, which partially diſſolves in water: it likewiſe precipitates ſilver from its ſolution in aquafortis. It acts more powerfully on copper; elevates a part of the metal in ſublimation, ſo as to acquire a bluiſh colour on the ſurface; and renders the greateſt part of the reſiduum ſoluble in water. This ſolution appears colourleſs, ſo that it could not be ſuppoſed to hold any copper; but readily diſcovers that it abounds with that metal, by the blue colour it acquires on an addition of volatile alkali, and the green calx which fixed alkalies precipitate. In evaporation it becomes green without addition. Iron is corroded by this ſalt in fuſion, and diſſolved by boiling in a ſolution of it. Zinc diſſolves more freely and more plentifully. Lead unites with it, but does not become ſoluble in water. Tin is corroded, and a part of the calx is ſoluble in boiling water. Of regulus of antimony alſo a ſmall portion is made ſoluble. Alkalies precipitate from the ſolution a bluiſh powder. Calcined biſmuth-ore treated with its equal weight of the ſalt, partly diſſolved in water into a pale red liquor, which became green from heat, in the ſame manner as tinctures made from that ore by aqua-regia. The undiſſolved part yielded ſtill, with frit, a blue glaſs. On treating manganeſe in the ſame manner, aluminous cryſtals were obtained: the undiſſolved part of the manganeſe gave ſtill a violet colour
635 to glaſs.

Gypſum. III. *With Calcareous Earth.* This combination may be made by ſaturating diluted oil of vitriol with chalk in fine powder. The mixture ought to be made in a glaſs; the chalk muſt be mixed with a pretty large quantity of water, and the acid dropped into it. The glaſs muſt be well ſhaken after every addition, and the mixture ought rather to be over ſaturated with acid; becauſe the ſuperfluous quantity may afterwards be waſhed off; the *ſelenite*, as it is called, or *gypſum*, having very little ſolubility in water.

This combination of vitriolic acid with chalk or calcareous earth, is found naturally in ſuch plenty, that it is ſeldom or never made, unleſs for experiment's ſake, or by accident. Mr Pott indeed ſays, that he found ſome ſlight differences between the natural and artificial gypſum, but that the former had all the eſſential properties of the latter. Vitriolic acid and its combinations.

The natural gypſums are found in hard, ſemitranſparent maſſes, commonly called *alabaſter*, or *plaſter of Paris*. (See ALABASTER, GYPSUM, and PLASTER.) By expoſure to a moderate heat, they become opaque, and very friable. If they are now reduced to fine powder, and mixed with water, they may be caſt into moulds of any ſhape: they very ſoon harden without ſhrinking; and are the materials whereof the common white images are made. This property belongs likewiſe to the artificial gypſum, if moderately calcined. 636

Mr Beaumé has obſerved, that gypſum may be diſſolved in ſome meaſure by acids; but is afterwards ſeparable by cryſtallization in the ſame ſtate in which it was before ſolution, without retaining any part of the acids. This compound, if long expoſed to a pretty ſtrong heat, loſes great part of its acid, and is converted into quicklime. In glaſs veſſels it gives over no acid with the moſt violent fire. It may be fuſed by ſuddenly applying a very intenſe heat. With clay it ſoon melts, as we have obſerved when ſpeaking of the materials for making crucibles. A like fuſion takes place when pure calcareous earth is mixed with clay; but gypſum bubbles and ſwells much more in fuſion with clay than calcareous earth. Beaumé's obſervations.

From natural gypſum we ſee that vitriolated tartar may be made, in a manner ſimilar to its preparation from green vitriol. If fixed alkaline ſalt is boiled with any quantity of gypſum, the earth of the latter will be precipitated, and the acid united with the alkali. If a mild volatile alkali is poured on gypſum contained in a glaſs, and the mixture frequently ſhaken, the gypſum will in like manner be decompoſed, and a *philoſophic* ſal ammoniac will be formed. With the cauſtic volatile alkali, or that made with quicklime, no decompoſition enſues. 637

IV. *With Argillaceous Earth.* The produce of this combination is the aſtringent ſalt called *alum*, much uſed in dyeing and other arts. It has its name from the Latin word *alumen* called στυπτηρια by the Greeks; though by theſe words the ancients expreſſed a ſtalactitic ſubſtance containing very little alum, and that entirely enveloped in a vitriolic matter. The alum uſed at preſent was firſt diſcovered in the oriental parts of the world; though we know not when, or on what occaſion. One of the moſt ancient alum-works of which we have any account was that of *Roccho*, now Edeſſa, a city of Syria: and from this city was derived the appellation of *Roch-alum*; an expreſſion ſo little underſtood by the generality, that it has been ſuppoſed to ſignify *rock-alum*. From this, and ſome works in the neighbourhood of Conſtantinople, as well as at Phocaea Nova, now Foya Nova, near Smyrna, the Italians were ſupplied till the middle of the 15th century, when they began to ſet up works of a ſimilar kind in their own country. The firſt Italian alum-work was eſtabliſhed about 1459 by Bartholomew Perdix, or Pernix, a Genoeſe merchant, who had diſcovered the proper matrix, or ore of alum, in the iſland of Iſchia. Soon after the ſame material was diſcovered at Tolſa by John de Caſtro, who had viſited the alum manufactories at Conſtantinople. Having

Alum of the ancients different from ours.

638 Whence the name of rock alum is derived.

639 Alum-works ſet up in Italy.

Vitriolic acid and its combinations.

vingobserved the ilex aquilifolium to grow in the neighbourhood of the Turkish manufactories, and finding the same near Tolfa, he concluded that the materials for alum were to be found there also; and was quickly confirmed in his suspicions by the taste of the stones in the neighbourhood. These alum-works prospered exceedingly, and their success was augmented by an edict of Pope Pius II. prohibiting the use of foreign alum.

640 In Spain, England, and Sweden.

In the 16th century an alum manufactory was erected at Alamaron, in the neighbourhood of Carthagena, where it still continues. Several others were erected in Germany; and in the reign of Queen Elizabeth one was erected in England by Thomas Chaloner. The preparation of this salt was not known in Sweden till the 17th century.

641 Its component parts first discovered by Mess. Boulduc and Geoffroy.

The component principles of this salt were long unknown; but at last Messrs Boulduc and Geoffroy discovered, that it consisted of argillaceous earth supersaturated with vitriolic acid. This is confirmed by the experiments of other chemists. It is found to redden the tincture and paper of turnsole; and on taking away the superabundant acid, it loses its solubility and all the other properties of alum. Mr Morveau, indeed, will not admit of a superabundance of acid in alum, which he thinks would necessarily be separated by edulcoration and crystallization; and he is of opinion with Mr Kirwan, that the turning vegetable juices red is not any unequivocal sign of the presence of an acid. In the present case, however, we certainly know that there is a superabundance of acid, and that a certain portion of the vitriolic acid adheres to the clay less tenaciously than the remainder. If we put a piece of iron into a solution of alum, it will attract this portion of acid; and the vitriolated clay when deprived of the superfluous quantity, will fall down to the bottom in an insoluble powder.

642 Mistake of Morveau detected by Mr Kirwan.

643 Alum deprived of its superfluous acid insoluble in water.

Alum in its ordinary state contains a considerable quantity of water, and crystallizes by proper management into octohedral and perfectly transparent and colourless crystals. When exposed to a moderate fire, it melts, bubbles, and swells up; being gradually changed into a light, spongy, white mass, called *burnt alum*. This, with the addition of some vitriolic acid, may be crystallized as before. The principles it contains, therefore, are water, vitriolic acid, and argillaceous earth. The proportions may be ascertained in the following manner. 1. The water and superfluous vitriolic acid may be dissipated by evaporation, or rather distillation; and the loss of weight sustained by the salt, as well as the quantity of liquid which comes over into the receiver, shows the quantity of aqueous phlegm and unsaturated acid. 2. By combining this with as much caustic fixed alkali as is sufficient to saturate the acid which comes over, we know its proportion to the water; and by redistilling this new compound, we have the water by itself. 3. The earth may be obtained by precipitation with an alkali in its caustic state, either fixed or volatile: but this part of the process is attended with considerable difficulty; for the alkalies first absorb the superfluous acid, after which the earth combined to saturation with the acid falls to the bottom, and the digestion with the alkaline salt must be continued for a very considerable time before the acid is totally separated. By analysing alum in this manner, Mr Bergman determined the principles of alum to be 38 parts of vitriolic acid, 18 of clay, and 44 of water, to 100 of the crystallized salt.

644 Bergman's method of finding the ingredients and their proportions.

645 Difficulty in obtaining the pure earth of alum.

646 Proportions of ingredients according to Mr Bergman.

It has been a question among chemists, whether the earth of alum is to be considered as a pure clay or not. The salt was extracted from common clay by Messrs Hellot and Geoffroy. The experiment was repeated with success by Mr Pott; but he seemed to consider it rather as the production of a new substance during the operation, than a combination of any principle already existing with the vitriolic acid. Margraaf, however, from some very accurate experiments, demonstrated, that all kinds of clay consist of two principles mechanically mixed: one of which constantly is the pure earth of alum. This opinion is espoused by Bergman; who concludes, that since an equal quantity of it may be extracted from clay by all the acids, it can only be mixed with these clays; for if it was generated by the menstrua during the operation, it must be procured in different quantities, if not of different qualities also, according to the difference of the solvents made use of. Notwithstanding this, the matter seems to be rendered somewhat obscure by an experiment of Dr Lewis. "Powdered tobacco-pipe clay (says he) being boiled in a considerable quantity of oil of vitriol, and the boiling continued to dryness, the matter when cold discovers very little taste, or only a slight acidulous one. Exposed to the air for a few days, the greatest part of it was changed into lanuginous efflorescences tasting exactly like alum. The remainder, treated with fresh oil of vitriol, in the same manner exhibits the same phenomena till nearly the whole of the clay is converted into an astringent salt." Hence he concludes, that the clay is in some degree changed before the aluminous salt is produced. Without this supposition, indeed, it is difficult to see why the salt should not be produced immediately by the combination of the two principles. An hundred parts of crystallized alum requires, according to Mr Bergman, in a mean heat 1412 parts of distilled water, but in a boiling heat only 75 of the same parts for its solution. The specific gravity of alum, when computed from the increase of bulk in its solution, is 2.071 when the air-bubbles are abstracted; but if they are suffered to remain, it is no more than 1.757. These bubbles consist of aerial acid, but cannot be removed by the air-pump, though they fly off on the application of heat.

647 Whether the earth of alum be a pure clay or not.

648 Component parts of all kinds of clay investigated by Margraaf.

649 Lewis's experiment, tending to show that clay undergoes some change in being converted into earth of alum.

650 Solubility of alum in warm and in cold water.

The ores from which alum is prepared for sale, according to Mr Bergman, are of two kinds: one containing the alum already formed, the other its principles united by roasting. What he calls the aluminous schist, is nothing but an argillaceous schist impregnated with a dried petroleum, from whence the oil is easily extracted by distillation; but by applying proper menstrua it discovers several other ingredients, particularly an argillaceous martial substance, frequently amounting to $\frac{3}{4}$ of the whole; a siliceous matter amounting to $\frac{1}{6}$; and commonly also a small proportion of calcareous earth and magnesia; the rest being all pyritous. By roasting this ore the bituminous part is destroyed and the pyrites decomposed; on which part of the vitriolic acid adheres to the iron of the pyrites, and the rest to the pure clay of the schist, forming green vitriol with the former, and alum with the latter. If any calcareous earth or magnesia are present, gypsum and Epsom salt will be produced at the same time. No salt is obtained by

651 Bergman's account of the Swedish ores of alum.

652 Component parts of the aluminous schist.

653 How changed by roasting.

by lixiviating this ſchiſt before calcination, thought Mr Bergman thinks nothing more is neceſſary for the production of the ſalt but the preſence of a pyrites. This, he tells us, is generally diſperſed through the maſs in

654 The preſence of pyrites only neceſſary for the production of alum.

form of very minute particles, though it ſometimes appears in ſmall nuclei. The goodneſs of the ore, therefore, depends on the proper proportion of the pyrites to the clay, and its equal diſtribution through the whole. The moſt denſe and ponderous is moſt eſteemed, while that which contains ſo much pyrites as to be viſible is rejected as having too much iron. The ore which produces leſs than four pounds of alum from 100 of the ore does not pay the expence of manufacturing in Sweden. Sometimes this kind of ore produces ſalts without the application of fire; but this muſt be attributed to a kind of ſpontaneous calcination.

655 Ores containing alum ready formed, only to be met with in volcanic countries.

That ſpecies of ore which contains the principles already united into alum, according to Mr Bergman, is to be met with only in volcanic countries; and of this kind are the principal Italian ores of alum, particularly that employed at Tolfa near Cincelles, for boiling the Roman alum. Mr Monnet, however, is of opinion, that even this ore does not contain alum perfectly formed, but a combination of nearly equal parts of clay and ſulphur, which by expoſure to air during calcination, is converted into alum. He found a little

656 Aluminous ore at Solfatara in Italy.

martial earth alſo contained in it, to which he aſcribes the reddiſh colour of that alum. The aluminous ore at Solfatara in Italy conſiſts of old lava whitened by the phlogiſticated vitriolic acid. The clay thus becomes a component part of the aluminous ſalt, and the maſs effloreſces in the ſame manner, and for the ſame

657 Analyzed by Mr Bergman

reaſon, as the maſs left after boiling tobacco-pipe clay in oil of vitriol mentioned by Dr Lewis. Mr Bergman, who examined this ore, found, that 100 pounds of it contained eight of pure alum, beſides four of pure clay; and that the remainder was ſiliceous. This proportion, however, muſt be very variable, according to the quantity of rain which falls upon the ore.

658 Aluminous ores in Haſſia, Bohemia, and Scania.

A variety of aluminous ores are to be met with in different parts of the world. In Haſſia and Bohemia this ſalt is obtained from wood impregnated with bitumen. At Helſingborg in Scania, a turf is found conſiſting of the roots of vegetables mixed with nuts, ſtraw, and leaves, often covered with a thin pyritous cuticle, which, when elixated, yields alum: Even the ſulphu-

659 Alum, ſulphur, and vitriol extracted from the ſame ore.

reous pyrites is generally mixed with an argillaceous matter, which may be ſeparated by menſtrua. In ſome places, ſulphur, vitriol, and alum are extracted from the ſame material. The ſulphur riſes by diſtillation; the reſiduum is expoſed to the air till it effloreſces, after which a green vitriol is obtained by lixi-

660 Alum ſlate found at York in England.

viation, and alum from the ſame liquor, after no more vitriol will cryſtallize. The *alum ſlate*, from which ſalt is made near York in England, contains a conſiderable quantity of ſulphur; and therefore produces alum on the principles already mentioned.

661 Bergman's directions for the preparation of alum.

Mr Bergman has given very particular directions for the preparation of this ſalt from its ores, and minutely deſcribes the ſeveral operations which they muſt undergo. Theſe are.

662 Uſe of roaſting the ore.

1. Roasting. This is abſolutely neceſſary in order to deſtroy the pyrites; for on this the formation of the alum entirely depends; as the ſulphur of the pyrites will not part with its phlogiſton without a burning heat in the open air. By long expoſure to the air, indeed, the ſame effect will follow; but unleſs the ore be of a particular kind, and looſe in texture, ſo that the air can freely pervade it, the proceſs we ſpeak of cannot

663 Expoſure to the air has ſometimes the ſame effect.

take place. The hard ores, therefore, cannot be treated in this manner; and the earthy ores are not only unfit for ſpontaneous calcination, but for roaſting

664 Earthy ores unfit for both operations.

alſo, as they will not allow the air to pervade them and extinguiſh the fire. Such as are capable of ſpontaneous calcination, ſhould be ſupplied with ſome quantity of water, and laid on a hard clay bottom, as directed for making green vitriol. The roaſting is performed in Sweden in the following manner. Small pieces of

665 Method of roaſting the ore in Sweden.

the ore are ſtrewed upon a layer of burning ſticks to the thickneſs of half a foot. When the ſticks are conſumed, theſe are covered, nearly to the ſame thickneſs, with pieces burned before and four times lixiviated: Thus ſtrata are alternately laid of ſuch a thickneſs, and at ſuch intervals of time, that the fire may continue, and the whole maſs grow hot and ſmoke, but not break out into flame. The upper ſtrata may ſometimes be increaſed to a double thickneſs on account of the long continuance of the fire. When eight ſtrata are laid, another row is placed contiguous to the former; when this is finiſhed, a third; and ſo on until the heap be of a proper ſize, which rarely requires more than three rows. When the ore is once roaſted, it ſtill contains ſo much phlogiſton that water

666 How often the operation is to be repeated.

acts but little upon it; but after the operation is two or three times repeated, the ore yields its principles more freely: the roaſting may even be repeated to advantage till the whole be reduced to powder. The bitumen keeps up the fire; for which reaſon alternate layers of the crude ore are uſed; and in rainy weather theſe layers of unburnt ore ſhould be thicker. An heap, 20 feet broad at the baſe, two feet at the top, and conſiſting of 26 rows, is finiſhed in three weeks, but requires two or three months to be well burned, and three weeks to cool. The greater pyritous nuclei explode like bombs. In this proceſs the ſulphur of the pyrites is ſlowly conſumed, and the phlogiſticated acid penetrating the maſs, is fixed; after which the re-

667 Danger of raiſing the heat too much.

maining phlogiſton is gradually diſſipated. The chief art conſiſts in moderating the heat in ſuch a manner as to avoid with ſafety the two extremes; for too ſmall a fire would not be capable of forming the ſalt, while a heat too ſtrong would deſtroy it by melting the ore. The ſcoria are inſoluble in water, and therefore thrown away as uſeleſs. They are produced by violent winds, or by a ſtrong heat too much cloſed up; for it is neceſſary to make holes in the red ſtrata, that the fire may reach the back ſtratum which is to be laid on.

668 Rinman's method of burning the ore at Garphyttan.

Another method of burning was invented by the celebrated Rinman, and is practiſed at a place called *Garphyttan* in Sweden. There the ore itſelf is ſet on fire; and after burning is boiled, and yields alum in the ſame manner as the former. The heaps are formed in the following manner: Firſt the ſchiſt, burning from the furnace, is laid to the depth of four feet; if the fire be ſlow, then wood is added; after that a thin ſtratum of elixated ſchiſt; the third conſiſts of ſchiſt not burned; and the fourth of elixated ſchiſt a foot and a half thick; after that the burning ſchiſt, and ſo on. This method, however, is attended with ſome inconveniences. The vitriolic acid is partly diſſipated by the fire, and thus the

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the quantity of alum is diminiſhed : ſo much ſchiſt alſo is requiſite in this method that it cannot all be elixated ; and thus the heap muſt be perpetually increaſing.

669 Method of burning the hard ores at Tolfa in Italy.

The hard ores containing bitumen, ſuch as thoſe of Tolfa, are burned upon wood for ſome hours like limeſtone, until they become pervious to water, and efforeſce. The fire is extinguiſhed as ſoon as the flame becomes white, and the ſmell of ſulphureous acid begins to be perceived. When the ore cools, thoſe particles which were neareſt to the fire are placed outermoſt, and thoſe which had been outermoſt within, the fire being again lighted. The ore is ſufficiently burned when it can be broken with the hands. It is then heaped up near certain trenches, and watered five times a-day, particularly when the ſun ſhines clear; the operation being deſtroyed by a continued rain and cloudy ſky. In ſome places the ore is firſt burned and afterwards elixated ; neither is there any way of knowing the proper methods of managing it but by experiment.

670 Method of elixating the burned ore at Garphyttan with cold water.

2. Elixation. This is performed in ſome places with hot, and at others with cold, water. At Garphyttan in Sweden, where the latter method is choſen, the receptacles, in the year 1772, were of hewn ſtone, having their joints united by ſome cement capable of reſiſting the liquor. Every ſet conſiſted of four ſquare receptacles diſpoſed round a fifth, which was deeper than the reſt. The firſt receptacle is filled with roaſted ſchiſt, and the ore lies in water for 24 hours ; the water is then drawn off by a pipe into the fifth; from thence into the ſecond, containing ſchiſt not yet waſhed ; from that in like manner, after 24 hours, through the fifth into the third, and ſo into the fourth The lixivium is then conveyed to the fifth, and allowed to ſtand in it; and laſtly is drawn off into a veſſel appro-

671 Other methods.

priated for its reception.—In other places the water paſſes over the ſchiſt that has been waſhed three times for ſix hours ; then that which has been twice waſhed, next what has been once waſhed, and laſtly, the ore

672 Singular circumſtance by which the alum may be deſtroyed.

which has been newly roaſted. Thoſe who ſuperintend the alum manufactories are of opinion that the alum is deſtroyed by paſſing the water firſt over the newly burnt ore, and then over that which has been previouſly elixated.

673 Of the proper ſtrength of the lixivium before boiling.

The lixivium, before boiling, ought to be as richly impregnated with alum as poſſible, in order to ſave fuel, though this is frequently neglected. In ſome places the taſte is uſed as the only criterion ; but in others the weight of water which fills a ſmall glaſs bottle is divided into 64 equal parts, each of which is called in Sweden a *panning*; and the quantity by which the ſame bottle, full of lixivium, exceeds it when filled with water, is ſuppoſed to indicate the quantity of ſalt diſſolved.—This method may undoubtedly be reckoned ſufficiently accurate for work conducted on a large ſcale : and though Mr Bergman gives formulae by which the matter may be determined to a ſcrupulous exactneſs, it does not appear that ſuch accuracy is either neceſſary or indeed practicable in works conducted in a great way.

Thoſe who manage the alum manufactories aſſert, that the cold lixivium ought to be made no richer than when the weight of the bottle filled with lixivium exceeds it when filled with water by $4\frac{1}{2}$ pannings, which ſhows the water to be loaded with $\frac{1}{14}$ of its weight of alum. If the overplus amounts to ſix pannings, which indicates its containing $\frac{1}{11}$ of ſalt, cryſtals are then depoſited.—Congelation is of no uſe to concentrate the aluminous lixivium ; for water ſaturated with alum freezes almoſt as readily as pure water.

674 Conſtruction of the evaporating veſſel.

3. Boiling the ley for chrystallization. The ley being firſt brought from the pits through canals made for the purpoſe, is put into a leaden boiler, at the back of which is a reſervoir, out of which the loſs ſuſtained by evaporation is conſtantly ſupplied, ſo that the ſurface of that in the boiler continues always nearly at the ſame height. Various ſigns are uſed by different manufacturers to know when the ley is properly evaporated : ſome determining the matter by the floating of a new laid egg; others by dropping a ſmall quantity on a plate, and obſerving whether it cryſtallizes on cooling; and laſtly, others weigh the lixivium in the bottle

675 Proper ſtrength of the evaporated liquor.

abovementioned. The boiling is ſuppoſed to be finiſhed if the increaſe of weight be equal to 10 pannings; that is, if the water be loaded with $\frac{1}{6.4}$ of its own weight. It might, however, take up above $\frac{2}{5}$ of its weight, or nearly 27 pannings ; but as it has to be depurated by ſtanding quiet before the cryſtals are formed, the liquor muſt not be fully ſaturated with ſalt.

676 Of the firſt cryſtallization.

The lixivium, when ſufficiently concentrated by evaporation, flows through proper channels into coolers, where it is allowed to reſt for about an hour to free it from the groſſer ſediment ; after which it is put into wooden or ſtone receptacles to cryſtallize. In eight or ten days the remaining liquor, commonly called *mother ley*, or *magiſtral water*, is let off into another veſſel. A great number of cryſtals, generally ſmall and impure, adhere to the bottom and ſides of the veſſel, which are afterwards collected and waſhed in cold water.

677 Depuration of the cryſtals.

When a ſufficient quantity of the ſmall cryſtals are collected, thy muſt then be put into the boiler for depuration. They are now diſſolved in as ſmall a quantity of water as poſſible ; after which the lixivium is poured into a great tub containing as much as the boiler itſelf. In 61 or 81 days the hoops of the tub are looſed, and the aluminous maſs bound with an iron ring ; and in 28 days more the reſiduum of the ſolution is let out through a hole, and collected in a trench ; after which the ſaline maſs, which at Garphyttan in Sweden amounts to 26 tons, is dried and ſold as depurated alum. The boiler emptied for the firſt cryſtallization is next filled two-thirds full with the magiſtral lixivium ; and as ſoon as the liquor arrives at the boiling point, the other third is filled with crude lixivium, with which the evaporation is alſo conſtantly ſupplied. A certain quantity of the aluminous impurities left by waſhing the ſalts of the firſt cryſtallization in water is then added, and the above deſcribed proceſs repeated. Only the firſt boiling in the ſpring is performed with the crude lixivium alone, the reſt

678 Bergman's remarks on the proper form of the coolers.

are all done as juſt now related.—Mr Bergman remarks, that the time required for cryſtallization may undoubtedly be ſhortened. The reſervoirs uſed in Sweden for this purpoſe (he ſays), are deep and narrow at the top ; on which account they are not only

long

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long in cooling, but the evaporation, which is abſolutely neceſſary for the cryſtallization, goes on very ſlowly, excepting in extremely warm weather, at the ſame time that the doors and windows are diſpoſed in ſuch a manner as to direct a current of air along the ſurface. In Italy he tells us that conical reſervoirs are uſed with the wide part uppermoſt.

679
Alum cannot be formed by merely evaporating and cooling the ley, on account of the exceſs of acid.

It is remarkable, that pure alum cannot be obtained in very conſiderable quantity by merely evaporating and cooling the ley. The reaſon of this is, that the lixivium ſometimes acquires ſuch a conſiſtence, that it both cryſtallizes with difficulty, and produces impure cryſtals. The cauſe was unknown till the time of Mr Bergman, who has ſhown that it proceeds from an exceſs of vitriolic acid. Hence alſo we may ſee the reaſon why alkaline ſalts, volatile alkali in its pure ſtate, or even putrefied urine, when added to this thick ſolution, produce good cryſtals of alum when they cannot be obtained otherwiſe. It is remarkable that this impediment to cryſtallization is not removed by mineral alkali, though it is ſo by the vegetable and volatile alkalies, which is a phenomenon hitherto unexplained. According to our author, however, an addition of pure clay, to abſorb the ſuperabundant acid, is preferable to any other; and indeed it is reaſonable to think ſo, as the union of vitriolic acid and pure clay forms the ſalt deſired, which is not the caſe with any of the alkalies. To aſcertain this, he made the following experiments.

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This exceſs cannot be removed by mineral alkali, though it may be by vegetable and volatile alkalies, and beſt of all by pure clay.

681
Experiment ſhowing that an exceſs of vitriolic acid impedes the cryſtallization of alum.

1. He diſſolved 215 grains of pure alum in diſtilled water, in a ſmall cucurbit, and evaporated it over the fire till the ſurface of the liquor ſtood at two marks, which indicated, in a former evaporation, that it was fit for cryſtallization. 2. Having poured out this into a proper glaſs veſſel, he diſſolved other 215 grains, and added to the ſolution $24\frac{1}{4}$ grains of concentrated vitriolic acid. 3. This ſolution being likewiſe poured out, the experiment was repeated a third time, with the addition of 53 grains of vitriolic acid; and the glaſſes being at laſt ſet in a proper place for cryſtallization, the firſt yielded $155\frac{3}{4}$, the ſecond 130, and the third $100\frac{1}{4}$ grains of alum.

682
Experiment to determine the uſefulneſs of adding clay to the ley.

This ſhows that an exceſs of vitriolic acid impedes the cryſtallization of the alum; but to determine how far this could be remedied by the addition of clay, farther experiments were neceſſary. Having therefore employed a magiſtral reſiduum, in which the exceſs of acid was nearly in the proportion already related, he added two drachms of clay in fine powder to a kanne, or Swediſh cantharus, of the liquor: he boiled the mixture for ten minutes; and on ſeparating the clay that remained, he found that $25\frac{1}{4}$ grains were diſſolved, which indicates an increaſe of 141 grains of alum. On gently boiling the liquor for half an hour, 75 grains of the clay were diſſolved, which indicated an increaſe of 416 grains of alum.

683
Advantages of uſing clay rather than alkalies.

The addition of clay muſt therefore be much preferable to that of alkaline ſalts, not only as the former produces a conſiderable increaſe of alum, but alſo as there is no danger of adding too much; for we have already ſhown, that when the liquor is entirely deprived of its ſuperabundant acid, the neutrallized clay is inſoluble in water. The earth itſelf, however, diſſolves ſo ſlowly, that there is not the leaſt danger of the acid being overſaturated by ſimply boiling them together.

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684
Alum generally contaminated by dephlogiſticated vitriol.

Alum, as commonly made, though depurated by a ſecond cryſtallization, yet is almoſt always found contaminated by dephlogiſticated vitriol; whence it grows yellow, and depoſits an ochre in ſolution when old. This is equally uſeful in ſome arts with the pureſt kind, and is even ſo in dyeing where dark colours are required; but where the more lively colours are wanted, every thing vitriolic muſt be avoided. This is done by the addition of pure clay, which precipitates the iron, and produces an alum entirely void of any noxious or heterogeneous matter. Nor is this contrary to the laws of chemical attraction; for though iron is diſſolved by a ſolution of alum, and the earthy baſe of alum precipitated, and though in a ſolution of vitriol and alum the white earth falls firſt on an addition of alkali, and then the ochre; this happens only in conſequence of employing phlogiſticated or metallic iron, or ſuch as is but very little dephlogiſticated; for if the inflammable principle be any further diminiſhed, the attraction is thereby ſo much weakened, that the clay has a greater attraction for the vitriolic acid than the iron. The truth of this may be proved in many different ways. Thus, let a portion of alum be diſſolved in a ſolution of highly dephlogiſticated vitriol, and an alkali then added, the ochre of the vitriol will be firſt depoſited and then the clay: and provided there be a ſufficient quantity of the latter, the iron will all be precipitated; and hence we ſee that an aluminous ſolution mixed only with one of dephlogiſticated vitriol may readily be freed from it.

685
This defect remedied by the addition of pure clay.

686
Perfect vitriol cannot be deſtroyed by clay.

But a ſolution of alum containing perfect vitriol cannot be freed from it effectually either by clay or alkali; for the former effects no decompoſition, and the latter, although it can deſtroy the vitriol, will undoubtedly decompoſe the alum in the firſt place. As long, therefore, as the ſolution is rich in alum, in may be employed in the common manner; but when the vitriolic ſalt begins to predominate, it muſt either be cryſtallized in its proper form, or be deſtroyed in ſuch a manner as to produce alum, which may be accompliſhed in the following manner. Let the lixivium be reduced to a tenacious maſs with clay, and formed into cakes, which muſt be expoſed in an houſe to the open air. Thus the phlogiſton, which is powerfully attracted by the dephlogiſticated part of the atmoſphere, by degrees ſeparates from the iron, while the clay is taken up by its ſuperior attraction for the acid. The calcination is accelerated by fire; but it muſt be cautiouſly employed, leſt the acid ſhould be expelled.

687
How the phlogiſton may be abſtracted from the vitriol.

688
Epſom ſalt may be produced from the mother liquor.

In the alum manufactories in Sweden, a conſiderable quantity of vitriolated magneſia, or Epſom ſalt, is mixed with the alum. Mr Bergman directs this to be ſeparated by means of an uncalcined calcareous earth, which entirely deſtroys both the alum and vitriol; falling down to the bottom with the acid in form of a ſelenitic matter. This muſt be added to the boiling liquor gradually, leſt the effervescence ſhould cauſe the maſs to ſwell and run over the top of the veſſel. A juſt proportion deſtroys both the aluminous and vitriolic ſalt, on being properly agitated and heated; neither is there any danger of the Epſom

ſalt

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ſalt being decompoſed in this proceſs, the uncalcined earth being unable to ſeparate the magneſia from the acid. Were this method followed in the Swediſh manufactories, he is of opinion, that as much Epſom ſalt might be produced from them as would ſupply the conſumpt of that kingdom.

689 Superfluous acid might be advantageouſly diſtilled.

With regard to the quantity of ſuperfluous acid found in the magiſtral lixivium, Mr Bergman informs us, that it amounted to five ounces in one kanne; ſo that in a ſingle boiler there is nearly 250 lb. But vitriol, when well dephlogiſticated, retains its acid ſo looſely that it may eaſily be ſeparated by fire. He has no doubt, therefore, that if the ſurface of ſuch a lixivium were firſt increaſed in order to let the phlogiſton evaporate, the liquor might afterwards be advantageouſly committed to diſtillation for the ſake of its acid.

From what has been above delivered the neceſſity will be ſufficiently apparent of not continuing the coction even with pure clay to perfect ſaturation of the liquor: and this is further confirmed by M. Beaumé, who relates, that having boiled four ounces of earth of alum with two ounces of the ſalt, in a ſufficient quantity of water, the acid became ſaturated to ſuch a degree with earth, that the liquor loſt its aluminous taſte entirely, and aſſumed that of hard ſpring water. After filtration and evaporation, only a few micaceous cryſtals, very difficult of ſolution, were formed by letting the liquor ſtand for ſome months.—— Dr Sieffert informs us, that by boiling half an ounce of alum with half a drachm of ſlaked lime, cubical cryſtals of alum may be obtained.

690 Epſom ſalt.

V. *With Magneſia.* The earthy ſubſtance called *magneſia alba* is never found by itſelf, and conſequently this combination cannot originally take place by art. The vitriolic acid, however, is found combined with magneſia in great plenty in the bitter liquor which remains after the cryſtallization of common ſalt; from whence the magneſia is procured by precipitating with a fixed alkali. If this liquor, which, when the common ſalt is extracted, appears like clean oil of vitriol, is ſet by for ſome time in a leaden veſſel, a large quantity of ſalt ſhoots, very much reſembling Glauber's ſal mirabile. This ſalt is in many places ſold inſtead of the true Glauber's ſalt; and is preferred to it, becauſe the true ſal mirabile calcines in dry air, which the ſpurious kind does not. If after the firſt cryſtallization of the bittern, the remainder is gently evaporated farther, a freſh quantity of Glauber's ſalt will ſhoot; and if the liquor is then haſtily evaporated, a ſalt will ſtill be cryſtallized; but inſtead of large regular cryſtals, it will concrete into very ſmall ones, having ſomething of the appearance of ſnow when taken out of the liquid. Theſe ſalts are eſſentially the ſame, and are all uſed in medicine as purgatives. The ſalt ſhot into ſmall cryſtals is termed *Epſom ſalt,* from its being firſt produced from the purging waters at Epſom in England. The bittern affording this kind of ſalt in ſuch great plenty, theſe waters were ſoon neglected, as they yielded it but very ſparingly, and the quantity prepared from them was inſufficient for the demand. Neumann ſays, that having inſpiſſated 100 quarts of Epſom-water, he ſcarce obtained half an ounce of ſaline matter.— According to Mr Scheele's experiments, if a ſolution of Epſom and common ſalt be mixed together, a double decompoſition enſues, and the mixture contains Glauber's ſalt and a combination of magneſia with marine acid. From this lixivium the Glauber's ſalt may be cryſtallized in winter, but not in ſummer; a great degree of cold being neceſſary for this purpoſe. From twelve pounds of Epſom ſalt and ſix of common ſalt, Mr Scheele obtained, in a temperature three degrees below the freezing point, ſix pounds of Glauber ſalt; but in a degree of cold conſiderably greater, the produce was ſeven pounds and three quarters.

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691 With ſilver.

VI. *With Silver.* Oil of vitriol boiled on half its weight of ſilver-filings, corrodes them into a ſaline maſs. This ſubſtance is not uſed in medicine nor in the arts. The only remarkable property of it is, that it has a very ſtrong attraction for mercury; coagulating and hardening as much quickſilver as the acid weighed at firſt. If the hard concrete be diluted with freſh acid, it melts eaſily in the fire, and does not part with the mercury in the greateſt heat that glaſs veſſels can ſuſtain. The vitriolic acid, by itſelf, ſtrongly retains mercury, but not near ſo much as when combined with ſilver.

Silver thus corroded by the vitriolic acid, or precipitated by it from the nitrous, may in great part be diſſolved, by cautiouſly applying a very little water at a time; and more effectually by boiling in freſh oil of vitriol.

692 Copper.

VII. *With Copper.* With this metal the vitriolic acid cannot be combined, unleſs in its concentrated ſtate, and ſtrongly heated. If pure oil of vitriol is boiled on copper filings, or ſmall pieces of the metal, it diſſolves it into a liquor of a deep blue colour, which eaſily cryſtallizes. The cryſtals are of a beautiful blue colour, and are ſold under the name of *blue vitriol,* or *Roman vitriol.*

693 Blue vitriol, how made.

Where ſulphur is found in great plenty, however, Roman vitriol is made by ſtratifying thin plates of copper with ſulphur; and upon ſlowly burning the ſulphur, its acid corrodes the copper. The metal is then to be boiled in water, that the ſaline part may be diſſolved. The operation is to be repeated till all the copper is conſumed; and all the ſaline liquors are to be evaporated together to the cryſtallizing point. By this method, however, a great part of the acid is loſt; and in Britain, where the ſulphur muſt be imported, we ſhould think the pure acid preferable for thoſe who prepare blue vitriol.

694 Phenomena on diſtillation.

This ſalt, on being expoſed to the fire, firſt turns white, then of a yellowiſh red colour. On urging it with a ſtrong fire, the acid ſlowly exhales, and a dark red calx of copper remains. The whole of the vitriolic acid cannot be expelled from copper by heat: as much of it ſtill remains as to render a part of the metal ſoluble in water. After this ſoluble part has been extracted, a little acid is ſtill retained amounting to about $\frac{1}{34}$ of the calx.

695 Uſes.

Vitriol of copper is employed in medicine as a cauſtic, in which reſpect it is very uſeful; but when uſed internally, is dangerous, as indeed all the preparations of copper are found to be. It has, nevertheleſs, according

Vitriolic acid and its combinations. cording to Neumann, been recommended in all kinds of intermittents, and the lepra. The ſmalleſt portion, he ſays, occaſions a ſickneſs and nauſea; a ſomewhat larger, reaching and violent vomitings, accompanied often with convulſions. If the quantity taken has been conſiderable, and is not ſoon diſcharged by vomiting, the ſtomach and inteſtines are corroded, intenſe pains, inflammations, and death, ſucceed.

696 Iron. VIII. *With Iron.* The vitriolic acid does not act upon this metal till conſiderably diluted. Common oil of vitriol requires to be mixed with ten or twelve times its quantity of water before it will act briſkly on the metal. In this ſtate it effervesces violently with iron filings, or ſmall bits of the metal, and a great quantity of inflammable vapour is diſcharged (ſee AIR). The liquor aſſumes a fine green colour; and by evaporation and ſlow coolings, very beautiful rhomboidal cryſtals

697 Salt of Steel are formed. Theſe are named *ſalt of ſteel*, and are uſed in medicine; but for the ſalt made of the pure acid and iron, the common copperas, made with the impure acid extracted from pyrites, is commonly ſubſtituted. This is generally eſteemed a venial fraud, and no doubt is ſo in medicinal reſpects; but when it is conſidered, that, by this ſubſtitution, common copperas is impoſed on the ignorant, at the price of 2 *s per* pound, the affair appears in a different light.

698 Precipitation of iron from the vitriolic acid. Pure vitriol of iron is originally of a much more beautiful appearance than common copperas, and retains its colour much better; the reaſon of which is, that the ſalt thus prepared has more phlogiſton than the copperas. If either of the kinds, however, are expoſed to the air for a ſufficient length of time, part of the acid is diſſipated, and the vitriol becomes yellowiſh or browniſh. If the ſalt is now diſſolved in water, a brown precipitate falls, which is part of the iron in a calcined ſtate. If the liquor is ſeparated from this precipitate by filtration, a ſimilar one forms in a ſhort time, and by long ſtanding a conſiderable quantity ſubſides. According to Dr Lewis, the precipitation is greatly expedited by a boiling heat; by which more of the metal ſeparates in a few minutes than by ſtanding without heat for a twelvemonth. This change takes place in no other metallic ſolutions.

699 Yellow for houſe painting. The calx of iron, precipitated by quicklime from green vitriol, appears, when dry of a yellow colour; and it is recommended in the Swediſh tranſactions, inſtead of yellow ochre, as a colour for houſe-painting.

700 Preſervative for wood. Solutions of green vitriol are alſo recommended for preſerving wood, particularly the wheels of carriages, from decay. When all the pieces are fit for being joined together, they are directed to be boiled in a ſolution of vitriol for three or four hours; and then kept in a warm place for ſome days to dry. By this preparation, it is ſaid, wood becomes ſo hard, that moiſture cannot penetrate it; and that iron nails are not ſo apt to ruſt in this vitriolated wood as might be expected, but laſt as long as the wood itſelf.

701. Tin. IX. *With Tin.* This metal cannot be diſſolved in the vitriolic acid, but in the ſame manner as ſilver; namely, by boiling concentrated oil of vitriol to dryneſs upon filings of the metal. The ſaline maſs may then be diſſolved in water, and the ſolution will cryſtallize. The ſalt, however, formed by this union, is not applied to any uſeful purpoſe. A ſalt of tin, indeed, formed by the union of vitriolic acid with this metal, has been recommended for ſome medical purpoſes, and proceſſes are given for it in the diſpenſatories; but they have never come much into practice.

X. *With Lead.* While lead is in its metallic ſtate, the vitriolic acid acts very little upon it, either in a diluted or concentrated ſtate; but if the metal is diſſolved in any other acid, and oil of vitriol added, a precipitation immediately enſues, which is occaſioned by the combination of vitriolic acid with the lead. This precipitate will be more or leſs white as the metal is more or leſs deprived of its phlogiſton by calcination before ſolution. If a little ſtrong ſpirit of nitre is poured upon *litharge*, which is lead calcined to the greateſt degree poſſible without vitrification, the acid unites itſelf to the metal with conſiderable effervescence and heat. Some water being now poured on, and the phial containing the mixture ſhaken, a turbid ſolution of the litharge is made. If a little oil of vitriol is then added, it throws down a beautifully white precipitate; and the acid of nitre, being left at liberty to act upon the remaining part of the litharge, begins anew to diſſolve it with effervescence. When it is again ſaturated, more oil of vitriol is to be dropped in, and a white precipitate is again thrown down. If any of the litharge is ſtill undiſſolved, the nitrous acid, being ſet at liberty a ſecond time, attacks it as at firſt; and by continuing to add oil of vitriol, the whole of the litharge may be converted into a moſt beautiful and durable white. Unfortunately this colour cannot be uſed in oil, though in water it ſeems ſuperior to any. If the proceſs is well managed, an ounce of ſpirit of nitre may be made to convert ſeveral pounds of litharge into a white of this kind. 702 Lead. 703 A beautiful white colour.

XI. *With Quickſilver.* The diſſolution of quickſilver in vitriolic acid cannot be performed but by a concentrated oil and ſtrong boiling heat. The metal is firſt corroded into a white calx, which may afterwards be eaſily diſſolved by an addition of freſh acid. Every time it is diſſolved, the mercury becomes more and more fixed and more difficult to dry. If the exſiccation and diſſolution has been repeated ſeveral times, the matter becomes at laſt ſo fixed as to bear a degree of red heat. This combination is the baſis of a medicine formerly of ſome repute, under the name of *turbith mineral*. The proceſs for making turbith mineral is given by the author of the Chemical Dictionary as follows. 704 Quickſilver.

"Some mercury is poured into a glaſs retort, and upon it an equal quantity of concentrated oil of vitriol, or more, according to the ſtrength of the acid. Theſe matters are to be diſtilled together, in the heat of a ſand-bath, till nothing remains in the retort but a dry ſaline maſs, which is a combination of the vitriolic acid and mercury. The acid which paſſes into the receiver is very ſuffocating and ſulphureous; which qualities it receives from the phlogiſton of the mercury. The white ſaline maſs which is left at the bottom of the retort is to be put into a large veſſel; and upon it are to be poured large quantities of hot water at ſeveral different times. The water weakens the acid, and takes it from the mercury; which is then precipitated towards the bottom of the veſſel, in form of a very ſhining yellow powder. The water with 705 Turbith mineral.

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which it is washed contains the acid that was united with the mercury, and likewise a little mercury rendered soluble by means of the very large quantity of acid.

Most chemists have believed, that a portion of vitriolic acid remains united with the turbith mineral, only too little to render it soluble in water. But Mr Beaumé, having examined this matter, affirms, that turbith mineral contains no acid, when it has been sufficiently washed; and that, by frequently boiling this preparation in a large quantity of distilled water, not a vestige of acid will adhere to it."

706 Dr Lewis's directions.

Dr Lewis, who is of opinion that the whole of this mercurial calx is soluble in a very large quantity of water, desires the water with which it is washed to be impregnated with some alkaline salt; which makes the yield of turbith greater than when pure water is used. The author of the Chemical Dictionary also observes, that the precipitate remains white till well freed from the acid; and the more perfectly it is washed, the deeper yellow colour it acquires.

707 Zinc.

XII. *With Zinc.* This semimetal is not acted upon by the vitriolic acid in its concentrated state; but, when diluted, is dissolved by it with effervescence, and with the extrication of an inflammable vapour in the same manner as iron. Neumann observes, that, during the dissolution, a grey and blackish spongy matter fell to the bottom, but, on standing for some days, was taken up, and dissolved in the liquor, nothing being left but a little yellowish dust scarcely worth mentioning. Six parts of oil of vitriol, diluted with an equal quantity of water, dissolves one part of zinc.

708 White vitriol.

The product of this combination is *white vitriol;* which is used in medicine as an ophthalmic, and in painting for making oil-colours dry quickly: what is used for this purpose, however, is not made in Britain, but comes from Germany. It is made at Goslar by the following process. An ore containing lead and silver, having been previously roasted for the obtaining of suphur (see METALLURGY), is lixiviated with water, and afterwards evaporated in leaden boilers, as for the preparation of green vitriol: but here a regular crystallization is prevented; for when the salt has assumed any kind of crystalline form, these crystals are made to undergo the watery fusion in copper caldrons. It is then kept constantly stirring till a considerable part of the moisture is evaporated, and the matter has acquired the consistence of fine sugar. White vitriol generally contains some ferruginous matter, from which it may be entirely freed by some fresh zinc; for this semimetal precipitates from the vitriolic acid all other metallic substances; but notwithstanding this strong attraction, the vitriolic acid is more easily expelled by distillation from white than green or blue vitriol. Towards the end of the distillation of white vitriol, the acid arises exceedingly concentrated, though sulphureous: so that, if mixed with common oil of vitriol, it will heat it almost as much as oil of vitriol heats water.

709 Regulus of antimony.

XIII. *With Regulus of Antimony.* To combine vitriolic acid with regulus of antimony, the same method must be used as directed for uniting it with quicksilver, for making turbith mineral, *viz.* to employ a very concentrated acid, and to distil in close vessels. The same phenomena also occur in this case as in making turbith mineral; a very suffocating sulphureous acid arises; and as Mr Geoffroy observes, a true sulphur sublimes into the neck of the retort; a white, saline, tumefied, mass remains in the vessel; and when the vessels are unluted, a white fume issues, as in the smoking spirit of libavius. See *Combinations of marine acid with tin,* infra.

710 Regulus of cobalt.

XIV. *With Regulus of Cobalt.* From a combination of the vitriolic acid with cobalt, a red salt may be obtained. To procure it, one part of cobalt, reduced to a very fine powder, may be mixed with two or three of concentrated acid, diluting the liquor after it has been digested for 24 hours, and then filtering and evaporating it.

711 Arsenic.

XV. *With arsenic.* Neumann relates, that powdered white arsenic being distilled in a retort with oil of vitriol, a transparent sublimate like glass arose, which in a few days lost its transparency, and became opaque like the arsenic itself. The arsenic remaining in the retort sustained an open fire without any sensible alteration. The author of the Chemical Dictionary says, that if a concentrated vitriolic acid is distilled from arsenic, the acid which comes over smells exactly like marine acid. When the solution is distilled till no more acid arises, the retort is then almost red-hot, and no arsenic is sublimed; but remains fused at the bottom of the retort; and, when cold, is found to be an heavy, compact mass, brittle and transparent as crystal-glass. This kind of arsenical glass, exposed to the air, soon loses its transparency from the moisture it attracts, which dissolves and partly deliquiates it. This deliquium is extremely acid—By digesting one part of arsenic with two of concentrated oil of vitriol, diluting the solution with water, and then filtering and evaporating, we obtain a yellowish salt which shoots into pyramidal, transparent, and shining crystals. None of the three last mentioned combinations have been found applicable to any useful purpose.

712 Oil.

XVI. *With Oil.* The product of this combination is a thick black substance, very much resembling balsam of sulphur in colour and consistence; to which it is sometimes substituted. If this substance is distilled with a gentle heat, great part of the acid becomes volatile, and evaporates in white fumes, having a pungent smell resembling that of burning sulphur. This goes by the name of *volatile* or *sulphureous vitriolic acid*; and a salt was formerly prepared from it by saturation with fixed alkali, which was thought to possess great virtues. From its inventor it was called the *sulphureous salt of Stahl.* The most singular property of this volatile acid is, that though the vitriolic in its fixed state is capable of expelling any other acid from its basis, the volatile one is expelled by every acid, even that of vinegar. It is very difficultly condensible, as we have already taken notice; and, when mixed with water, seems scarcely at all acid, but rather to have a bitterish taste.

713 Volatile sulphureous acid.

Several methods have been proposed for procuring this acid from burning sulphur, which yields it in its greatest degree of volatility, as well as concentration; but the produce is so exceedingly small, that none of them are worth mentioning. Dr Priestley has given very good directions for obtaining the volatile vitriolic acid in the form of air. His method was, to pour, on some

714 How procured by Dr Priestley.

Vitriolic acid and its combinations. some oil of vitriol contained in a phial, a very small quantity of oil olive; as much as was sufficient to cover it. He then applied the proper apparatus for the reception of air in quicksilver (see AIR); and, holding a candle to the phial, the volatile vitriolic acid rushed out in great quantity. Had he received this air in water, instead of quicksilver, the consequence would have been, that some part of it, at least, would have been absorbed by the water, and a sulphureous acid liquor produced. This seems indeed almost the only method of procuring the sulphureous vitriolic acid of any tolerable strength; but it is never required in the form of a liquor, except for experimental purposes. The only useful property hitherto discovered about this kind of acid is, that it is remarkably destructive of colours of all kinds; and hence the fumes of sulphur are employed to whiten wool, &c.

715 Charcoal. XVII. *With Phlogiston of charcoal.* If charcoal is mixed with concentrated vitriolic acid, and the mixture distilled, the same kind of acid is at first obtained, which comes over when oil is used; and towards the end, when the matter begins to grow dry, a true sulphur sublimes. The best way, however, of producing sulphur from the vitriolic acid is by combining it, when in a perfectly dry state, with the phlogiston. By this means sulphur may very readily be made at any time. The process is generally directed to be performed in the following manner.

716 Sulphur prepared from vitriolated tartar. Reduce to fine powder any quantity of vitriolated tartar. Mingle it carefully with a 16th part of its weight of charcoal-dust. Put the whole into a covered crucible set in a melting furnace. Give a heat sufficient to melt the salt; and when thoroughly melted, pour it out on a flat stone. The vitriolated tartar and charcoal will now be converted into a sulphureous mass, similar to a combination of alkaline salts with sulphur. See *Alkaline Salts*, below.

717 Spirit of wine. XVIII. *With Spirit of wine.* The result of this combination is one of the most extraordinary phenomena in chemistry; being that fluid, which, for its extreme degree of volatility, was first distinguished by the name of *ether*: and now, since a liquor of the like kind is discovered to be preparable from spirit of wine by means of other acids, this species is distinguished by the name of *vitriolic ether*. The method of preparing this subtle liquor recommended by M. Beaumé, seems to be the best of any hitherto discovered.

718 Ether. Mix together equal parts by weight, of highly rectified spirit of wine and concentrated oil of vitriol, or somewhat more than two measures of spirit of wine with one of the acid. The mixture is to be made in a flint glass retort, the bottom and sides of which are very thin, that it may not break from the heat which is suddenly generated by the union of these two substances. The spirit of wine is first put into the retort, and then the acid is poured in by a glass-funnel, so that the stream may be directed against the side of the glass; in which case it will not exert much of its force on the spirit, but will lie quietly below at the bottom. The retort is now to be very gently shaken, that the acid may mingle with it by little and little. When the mixture is completed, very little more heat will be necessary to make the liquor boil.

This mixture is to be distilled with as brisk and quick a heat as possible; for which reason, immediately after the acid and spirit are mixed, the retort should be put into a sand furnace heated as much as the mixture is. The distillation should be continued only till about one-third of the liquor is come over; if it is continued farther, part of the vitriolic acid rises in a sulphureous state. In the retort a thick, black, acid matter remains, which is similar to a combination of oil of vitriol with any inflammable matter, and from which a little sulphur may be obtained. Along with the sulphureous acid, a greenish oil, called *oleum vitrioli dulcis*, arises, which has a smell compounded of that of the ether and sulphureous acid: and Mr Beaumé has shown that it is compounded of these two; for if it is rectified with an alkali, to attract the acid, it is changed into ether. If, after the distillation of the ether, some water be poured into the retort, the liquor by distillation may be brought back to the state of a pure vitriolic acid.

As the steams of the ethereal liquor are exceedingly volatile, and at the same time a quick fire is necessary to the success of the operation, the receiver must be carefully kept cool with very cold water or with snow. Care must also be taken to prevent any of the sulphureous acid steams from coming over; but as it is impossible to prevent this totally, the liquor requires rectification. This is the more necessary, as a part of the spirit of wine always rises unchanged. From this acid the liquor is easily set free, by adding a small quantity of alkaline salt, and re-distilling with a very gentle heat; but as spirit of wine is likewise very volatile, the distillation must be performed in a very tall glass. Dr Black recommends a matrass, or bolt-head, with a tin-pipe adapted to the head, so as to convey the steams at a right angle, to be condensed in the receiver. When this fluid is to be prepared in great quantities, the ether, by proper management, may be made to equal half the weight of the spirit of wine employed. Mr Dollfuss has made many important experiments on this subject; of which the following is an abstract: 1. Two pounds of vitriolic acid were mixed with as much of spirit of wine, and the mixture distilled with a very gentle fire. The first ten ounces that came over consisted of a liquor strongly impregnated with ether, and of an agreeable odour. This was put by itself and marked A. It was followed by a stronger ethereal liquor, of which a small quantity only would mix with water. Of this there were 12 ounces, which were also put by themselves, and marked B. By continuing the process two ounces more were obtained, which smelled of sulphur, and were marked C. The distillation was now continued with a view to concentrate the vitriolic acid, when three drachms of a thicker kind of ether were found swimming on a weak sulphureous acid. This thick liquid was not in the least volatile, and in consistence resembled an expressed oil. 2. Twenty-four ounces of spirit of wine were now added to the residuum of the former distillation, and the process recommenced. The first seven ounces that came over were poured to the dulcified spirit marked A. Next passed over ten ounces of a tolerably pure ether, which was mixed with the contents of B; besides two ounces that had a sulphureous smell, which were mixed with C. By a repeated dephlegmation of what remained in the retort were obtained five ounces of a weak sulphureous acid; and

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the remainder being again mixed with 20 ounces of spirit of wine, yielded first six ounces of the liquor marked A; then four ounces of pure ether put into that marked B; and after that another ounce marked C. By continuing the distillation four ounces of weak sulphureous acid were obtained, on which floated a little oil of wine. 3. The remainder, which was very thick, and covered with a slight pellicle, was mixed with 20 ounces of spirit of wine, and yielded five ounces of dulcified spirit marked A; eight ounces of pure ether marked B; and at last one ounce of the same, which had rather a sulphureous smell. This was followed by a few drops of acid; but the remainder frothed up with such violence, that an end was put to the operation, in order to prevent its passing over into the receiver.

By these four distillations there were obtained from six pounds of spirit of wine and two of oil of vitriol, 28 ounces of dulcified spirit of vitriol and 38 of ether; which last, when rectified by distillation over manganese, yielded 28 ounces of the best ether. At the end of this distillation were produced 13 ounces of weak acetous acid; and the liquor of the last running marked C, afforded, by rectification, four ounces of good ether. The sulphureous acid liquor yielded four ounces of weak acetous acid, and three drachms of naphtha resembling a distilled oil in consistence.

By these processes the vitriolic acid was rendered quite thick and black; its weight being reduced to 24 ounces. The blackness was found to be owing to a powder which floated in the liquid, and could neither be separated by subsiding to the bottom nor rising to the top. The liquor was therefore diluted with eight ounces of water, and filtered through powdered glass; by which means the black substance was collected, partly in powder, and partly in grains of different sizes. It felt very soft between the fingers, and left a stain upon paper like Indian ink; but though washed with 24 ounces of water, still tasted acid. Half an ounce of it distilled in a retort yielded a drachm and an half of weak acetous mixed with a little sulphureous acid; the residuum was a black coal, which by calcination in an open fire for a quarter of an hour, yielded 25 grains of white ashes, consisting of selenite, calcareous earth, and magnesia. A drachm of it digested with nitrous acid, which was afterwards distilled from it, and then diluted with distilled water and filtered, yielded a few crystals, which appeared to be genuine salt of tartar, an insoluble selenite being left behind. On rectifying the vitriolic acid freed from the black matter and diluted with eight ounces of water, nine ounces of sulphureous acid were first obtained, after which followed an ounce of acid rather high-coloured, and then the vitriolic acid quite colourless. It now weighed only 19¾ ounces, and its specific gravity was but 1.723, while that of the acid originally employed had been 1.989.

On repeating the process with six pounds of spirit of wine to two of oil of vitriol, the first 12 ounces that came over were spirit of wine almost totally unchanged; then two ounces smelling a little of ether; and afterwards two pounds, of which about one-third were ether. When about five pounds had been drawn off, the distilling liquor began to smell sulphureous; and after nine ounces more had been drawn off, the frothing up of the matter in the retort obliged him to put an end to the operation. The acid was then filtered through pounded glass as before, and afterwards committed to distillation. The three first ounces were a weak sulphureous acid; then followed an ounce more concentrated, and of a red colour; then another of a yellowish cast; after which the rest of the acid came over quite colourless. The whole weighed 27 ounces, and the specific gravity of it compared with distilled water was as 1.667 to 1.000.

719 Properties of ether.

Ether is the lightest of all known fluids, except air; and is so volatile, that *in vacuo* its boiling point is 20° below 0° of Fahrenheit's thermometer. If a small quantity is poured out on the ground, it instantly evaporates, diffusing its fragrance all through the room, and scarce perceptibly moistening the place on which it fell. It difficultly mixes with water, as being of an oily nature: ten parts of water, however, will take up one part of ether. Its great volatility renders it serviceable in nervous diseases, and removing pains, when rubbed on with the hand, and kept from evaporating immediately. By spontaneous evaporation, it produces a great degree of cold. (See EVAPORATION and CONGELATION). The most extraordinary property, however, is, that if gold is dissolved in aqua-regia) see *Metallic Substances*, below), and ether added to the solution, the gold will leave the acid and permanently unite with the ether. The exceeding great volatility of ether renders it very easily inflammable even on the approach of flame; and therefore it ought never to be distilled, or even poured from one vessel to another, by candle-light. If a less quantity of the vitriolic acid is added to the spirit of wine than what is sufficient to produce ether, the product is called *spiritus vitrioli dulcis*. The following experiment made by Wallerius, induced him and others to think, that the vitriolic acid was convertible into the nitrous.

720 Experiment in favour of the transmutation of vitriolic into nitrous acid.

"Some salt of tartar (says he) being mixed with the dulcified spirit of vitriol, or perhaps with the ether (for the author expresses himself a little ambiguously), the full bottle stopt with a cork, tied over with bladder, and laid on its side; on standing for four months, the greatest part of the spirit was found to have escaped, and the salt was shot into hexangular prismatic crystals resembling nitre. It tasted strongly of the spirit, but had no other particular taste. Laid on a burning coal, it crackled, exploded with a bright flash, and flew into the air. He afterwards found, that by adding to the spirit a drop or two of any acid, the salt crystallizes the sooner; that in this case it has a sourish taste, but in other respects is the same with that made without acid. This salt-petre (says the author) promises, from the violence of its explosion, to make the strongest gun-powder in the world, but a very dear one. Though the experiment should not be applicable to any use in this way, it will probably contribute to illustrate the generation of nitre: as it palpably shows nitre, that is, the acid or characteristic part of nitre, produced from the vitriolic acid and phlogiston.

721 Not conclusive.

We cannot here help again regretting that chemists of superior abilities should sometimes leave very important discoveries only half finished, so that chemists of an inferior rank know not what to make of them. Had Wallerius,

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Wallerius, who seems more than once to have been in possession of this salt, only poured on it a few drops of oil of vitriol, the peculiar colour and smell of its fumes must have been a much more convincing proof of the reality of the transmutation than that of mere deflagration; because the latter can be otherwise accounted for.

722
Violent explosions from the application of heat.

It is certain, that many sustances, water itself not excepted, will explode with great violence if suddenly heated beyond what they are able to bear. If spirit of wine is confined in a close vessel, it will also by means of heat burst it as effectually as water; and as the vapours of this substance are inflammable, the explosion will be attended with a flash if any flame is near. In like manner ether, on the approach of a candle, takes fire, and goes off in a flash like lightning; but this happens, not from any thing nitrous, but from its great volatility and inflammability. If therefore the vapours of the ethereal liquors are confined, and heat is applied suddenly to the containing vessel, their great volatility will cause them make an instantaneous effort against the sides of it, which increasing with a swiftness far beyond that of aqueous or spirituous vapours, will make a much quicker as well as a much stronger explosion than either of them; and if a flaming substance is near, the explosion will be attended with a bright flash like that of the ether itself.

In the experiment now before us, the salt tasted strongly of the spirit, or ether, from which it was made. The spirit was therefore confined in the crystals of salt; and this volatile liquor, which, even under the pressure of the atmosphere, boils with the heat of 100° of Fahrenheit, was, in a confined state, subjected to the heat of a burning coal; that is, to more than ten times the degree of heat necessary to convert it into vapour. The consequence of this could be no other, than that the particles of salt, or perhaps the air itself, not being capable of giving way soon enough to the forcible expansion of the ether, a violent explosion would happpen, and the salt be thrown about; which accordingly came to pass, and might very reasonably be expected, without any thing nitrous contained in the salt.

2d 722
Cavallo's method of purifying ether.

Mr Cavallo describes an easy and expeditious method of purifying ether, though a very expensive one; as out of a pound of the common kind scarce three or four ounces will remain of that which is purified. The method of purifying it, he says, was communicated to him by Mr Winch chemist in London, and is to be performed in the following manner. "Fill about a quarter of a strong bottle with common ether, and pour upon it twice as much water; then stop the bottle and give it a shake, so as to mix the ether for some time with the water. This done, keep the bottle for some time without motion, and the mouth of it downwards, till the ether be separated from the water, and swims above it; which it will do in three or four minutes. Then opening the bottle with the mouth still inverted, let the greatest part of the water run out very gently; after this, turn the bottle with the mouth upwards; pour more water upon the ether, shaking and separating the water as before. Repeat this operation three or four times; after which the ether will be exceedingly pure, and capable of dissolving elastic gum, though it could not do so before."

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As great part of the ether undoubtedly remains mixed with the water after this process, our author remarks, that it might be worth while to put the water into a retort and distil the ether from it, which will come sufficiently pure for common use. He observes also, that "it is commonly believed that water combines with the purest part of the ether when the two fluids are kept together; though the contrary seems to be established by this process. According to Mr Wastrumb, we may obtain from the residuum of vitriolic ether a resin containing vitriolic acid, vinegar, Glauber's salt, selenite, calcareous earth, silex, iron, and phosphoric acid.

§ 2. *Of the* Nitrous *Acid and its Combinations.*

This acid is far from being so plentiful as the vitriolic. It has been thought to exist in the air; and the experiments of Mr Cavendish have shown, that it may be artificially composed, by taking the electric spark in a mixture of dephlogisticated and phlogisticated air. See Aerology, n° 77.

724
Of the preparation of nitre.

With regard to the preparation of nitre, Dr Black observes, that it is made in great plenty in the more southern parts of Europe; likewise in the southern parts of Persia, in China, the East Indies, and in North America. We have had no accounts of the manner in which it is prepared in the East Indies, no person on the spot having taken particular notice of the manufacture. The general account is, that it is obtained from the soil of certain districts which are called *saltpetre grounds*; where the soil is very cold, barren, and unhealthy. The salt is there ready formed by nature. It is only necessary to gather large quantities of the earth, and to put it into a cavity through which a great quantity of water is poured, which dissolves the nitre; and the lixivium runs into an adjacent pit, out of which it is lifted in order to be evaporated and obtained in the form of crystals. This account, however, has been thought unsatisfactory; because there is hardly any part of Europe in which it is found in this manner. It is discovered indeed in some very large districts in Poland, particularly in Podolia, where the country is flat and fertile, and had been once very populous, but is now in a great measure deserted. It is there obtained from tumuli or hillocks, which are the remains of former habitations; but these are the only places in which it is found in any considerable quantity. In Spain, it is said that the inhabitants extract it from the soil after a crop of corn. It has been found in America in lime-stone grounds, in the floors of pigeon-houses, tobacco-houses, or the ruins of old stables, where a number of putrefying vegetables were once collected. In general, however, it is extracted from artificial compounds or accidental mixtures, where animal and vegetable substances have been fully putrefied by being exposed to the air with any spongy or loose earth, especially of the calcareous kind, and open to the north or north-east wind, and more or less covered from the heat or rains. This last particular is absolutely necessary to its formation in any quantity; for the heat, by evaporating the moisture too much, prevents it from being produced, and the rains wash it away after it is already made. Cramer, an author of the greatest credit, informs us in his Docimastics, that he made a little hut exposed to the fresh air of the country,

725
Discovered in some places in Podolia in Poland;

726
In Spain and America.

727
Requisites for its formation.

728
Cramer's artificial compost for making nitre.

Nitrous acid and its combinations.

country, with windows to admit the winds. In this he put a mixture of garden mold, the rubbiſh of lime, and putrid animal and vegetable ſubſtances. This he frequently moiſtened with urine; and in a month or two found his compoſition very rich in nitre, yielding at leaſt one-eight part of its weight.

729 How prepared in Hanover.

It is manufactured in Europe by making artificial compounds with leſs trouble. In Hanover it is got by collecting the rakings of the ſtreets; which are built up into mud-walls that are allowed to remain a certain time, when the ſurface is found covered with a white ſaline efflorescence. A perſon is employed to ſcrape this off; and putting it into a veſſel, it is waſhed with water to diſſolve the nitre, and the remaining earthy matter is again plaſtered on the mud-walls, and freſh matter brought from the ſtreets to renew them occaſionally: and by this ſimple method a conſiderable quantity is obtained.

730 In other parts of Germany.

In Germany the peaſants are directed by law to build mud-walls of this kind with the dung and urine of animals, and ſome ſtraw. After they have ſtood for ſome time, and the vegetable and animal ſubſtances are rotten, they afford a conſiderable quantity of nitre.

731 In France.

In France it is obtained from accidental collections of this kind; as where looſe earth has been long expoſed to the contact of animal ſubſtances, as the ruins of old ſtables, pigeon-houſes, &c. Sometimes from the mould upon the ground where dunghills have been lying. A particular ſet of people go about in ſearch of theſe materials; and when, by making a ſmall eſſay, they find that they will turn to account, they put the materials into a large tub with a perforated bottom, and another which is water-proof put below it. Some ſtraw is interpoſed betwixt the two; and on pouring water upon the materials, it ſoaks through them, undergoes a kind of filtration in paſſing through the ſtraw, and is then drawn off by a cock placed in the the under-tub, and boiled to a proper conſiſtence for cryſtallization. The cryſtals are at firſt brown and very impure, but by repeated diſſolution and cryſtallization become pure and white.

732 Dr Black's concluſions concerning the nature of ſalt-petre.

From theſe particulars relating to the hiſtory of ſalt-petre, Dr Black concludes, that it is not properly a foſſil, being produced at the ſurface of the ground. Margraaf diſcovered a ſmall quantity of it in the analyſis of ſome of the waters about Berlin, and others have found it in the wells about ſome great cities: but no true nitre has ever been found in ſprings; ſo that this nitrous ſalt may be ſuppoſed to have derived its origin from the quantity of putrid matters with which all cities abound. All rich and fertile ſoils are found to contain it; and in the hot countries, where the products of nature are numerous, and putrefaction carried on very faſt, they are often very rich in nitre. This may happen in ſome places from the conflux of waters; which remaining for ſome time on the ſurface, and afterwards exhaling, left the ſaline particles behind.

733 Suppoſed to be the laſt effect of putrefaction.

On the whole, Dr Black concludes, that neither nitre nor its acid does exiſt in the air, becauſe it might eaſily be detected there; though many have embraced this opinion from its being uſually found at the ſurface of the ground. He is of opinion, that it is the effect of the laſt ſtage of putrefaction of animal and vegetable ſubſtances; and it is never to be found except where theſe or their effluvia are preſent, and never till the putrefaction is complete. It has been a matter of diſpute, whether it exiſted in thoſe matters before the proceſs of putrefaction, or was produced by it. But it is pretty certain, ſays the Doctor, that it originated in them; for the ſun-flower, tobacco, and other plants, are found to contain it before putrefaction: and ſome have even aſſerted, that plants placed in the earth, deprived of all its ſaline ſubſtances, will yield it. The compoſitions recommended by Cramer are the fitteſt for producing a complete degree of putrefaction, provided they contain a moderate degree of humidity, and that the quantity expoſed to the air be defended from too great a heat by the ſun, which would dry up its moiſture; and likewiſe from too great a degree of cold, which likewiſe checks fermentation. The importance of the calcareous earth in ſuch a compoſition would likewiſe favour the concluſions juſt now drawn; for the moſt remarkable effect of this earth is to promote and perfect the putrefaction of theſe ſubſtances. It would ſeem, therefore, that the true ſecret of the production of nitre is to mix properly together animal and vegetable ſubſtances with earth, particularly of the calcareous kind; expoſing them to the air with a moderate degree of humidity, ſufficient to promote their putrefaction in the moſt effectual manner; and when the putrefaction is carried to the utmoſt height, we may then expect that nitre will be produced.

734 Diſtinguiſhing characteriſtic of the nitrous acid.

The diſtinguiſhing characteriſtic of the nitrous acid is its great diſpoſition to unite with the phlogiſton; and, when ſo united, firſt to become exceedingly volatile, and at laſt to be diſſipated in a very white bright flame: this is called its *detonation* or *deflagration*. In the ſtrongeſt ſtate in which this acid is procurable in a liquid form, it is of a reddiſh yellow colour, and continually exhales in denſe, red, and very noxious fumes; and in this ſtate is called *ſmoking*, or, from its inventor, *Glauber's*, ſpirit of nitre.

I. To extract the Nitrous Acid by means of the *Vitriolic*.

735 Spirit of nitre.

Into a glaſs retort put two pounds of good ſalt-petre, and pour upon it 18 ounces of concentrated oil of vitriol; ſet the retort in a ſand-heat, and lute on a large receiver with the compoſition already recommended, for reſiſting acid fumes; the mixture will grow very warm, and the retort and receiver will be filled with red vapours. A ſmall fire is then to be kindled, and cautiouſly raiſed till no more drops will fall from the noſe of the retort. What comes over will be a very ſtrong and ſmoking ſpirit of nitre.

736 Rectification.

In this proceſs, the nitrous acid is generally mixed with part of the vitriolic which comes over along with it, and from which it muſt be freed if deſigned for nice purpoſes. This is moſt effectually done by diſſolving in it a ſmall quantity of nitre, and rediſtilling the mixture. The vitriolic acid which came over in the firſt diſtillation is kept back by the nitre in the ſecond, combining with its alkaline baſis, and expelling a proportionable quantity of the nitrous acid.

737 Different methods of diſtilling.

We have here directed the pure vitriolic acid to be uſed, in order to expel the nitrous one; but for this purpoſe any combination of the vitriolic acid with a metallic or earthy baſis may be uſed, though not with equal advantage. If calcined vitriol is made uſe of,

as

Nitrous acid and its combinations.

as much phlogiston is communicated by the calx of iron contained in that salt as makes the nitrous acid exceedingly volatile, so that great part of it is lost. If calcined alum, or selenite, is made use of, the vitriolic acid in these substances immediately leaves the earth with which it was combined, in order to unite with the alkaline basis of the nitre, and expels its acid: but the moment the nitrous acid is expelled from the alkali, it combines with the earth which the vitriolic acid had left; from which it cannot be driven without a violent fire; and part of it remains obstinately fixed, so as not to be expelled by any degree of heat. Hence the produce of spirit, when nitre is distilled with such substances, always turns out considerably less than when the pure vitriolic acid is used. Alum is preferable to selenite, for the purposes of distilling spirit of nitre; because the acid does not adhere so strongly to argillaceous as to calcareous earth.

According to Weigleb, the nitrous acid may be expelled not only by clay, gypsum, and other substances containing the vitriolic acid, but even by various kinds of vitrifiable earth. Clean pebbles, quartz in the form of sand, pieces of broken china and stone ware, powdered glass, *&c* mixed with nitre in the proportion of six to one, always expel the acid, though imperfectly. In France the acid is always extracted by means of clay.

The reason of these decompositions is, that the alkaline basis of the nitre attracts the siliceous earth, whose fixedness in a vehement fire gives it an advantage over the volatile nitrous acid, in the same manner that the weak acid of phosphorus or arsenic will also expel it by reason of their fixedness in the fire.

Even spirit of salt, according to Margraaff's experiments, may be used for distilling the spirit of nitre. That celebrated chemist informs us, that on distilling nitre with eight or nine times its quantity of strong marine acid, a spirit comes over which consists chiefly of the nitrous acid, but has also some portion of that of sea salt. The reason of this is shown in Mr Kirwant's experiments on chemical attractions*. In the present case, however, the decomposition may be facilitated by the strong attraction of the nitrous acid for phlogiston; for it is well known, that on mixing the nitrous and marine acids together, the latter is always dephlogisticated. It seems therefore that in this case a double decomposition takes place, the nitrous acid uniting itself to the phlogiston of the marine, and the latter attaching itself to the alkali of the nitre.

* See n° 292.

738 Uses. Spirit of nitre is very useful in the arts of dyeing and refining, where it is known by the name of *aquafortis*; and therefore an easy and cheap method of procuring it is a valuable piece of knowledge. Many difficulties, however, occur in this process, as well as that for the vitriolic acid. Oil of vitriol, indeed, always expels the nitrous acid with certainty; and on distilling the mixture, a spirit of nitre arises; but if a glass retort is used for the purpose of distilling this acid, the quantity of residuum left in distillation is so great, and so insoluble in water, being no other than vitriolated tartar, that the retort must always be broken in order to get it out; and the produce of spirit will scarce afford the breaking a retort. If earthen retorts are made use of, they must certainly be of that kind called stone-ware, and the price of them will be very little if at all inferior to that of glass. Iron pots are said to be made use of in the distillation of common aquafortis in large quantities; but they have the great inconvenience of making a quantity of the acid so volatile, that it not only will not condense, but spreads its suffocating vapours all round in such a manner as to prove very dangerous to those who are near it. If an iron vessel, therefore, is thought of for the purpose of distilling aquafortis, it will be proper at least to attempt luting over the inside with a mixture of gypseous earth and sand, to prevent as much as possible the acid from attracting the metal.

Dephlogisticated spirit of nitre is obtained by distilling the smoking kind with a gentle heat, until what remains is as colourless as water. It is distinguished by emitting white and not red fumes like the other kind, when set in a warm place. It must be kept constantly in the dark, otherwise it will again become phlogisticated, and emit red vapours by the action of the light; the same thing will also take place if it be heated with too violent a fire.

II. To procure the Nitrous Acid by means of *Arsenic*.

Pulverise equal quantities of dried nitre and white crystalline arsenic; mix them well together, and distil in a glass-retort with a fire very cautiously applied; for the arsenic acts on the nitre with such a violence, and the fumes are here so volatile, that unless great care is taken, a most dangerous explosion will almost certainly happen. As, in this case, the nitrous fumes arise in a perfectly dry state, some water must be put into the receiver, with which they may unite and condense. The aquafortis so produced will have a blue colour, owing to the inflammable principle separated from the arsenic, by which its extreme volatility is likewise occasioned. If this blue aquafortis is exposed to the air, its colour soon flies off. If instead of the white arsenic we employ the pure arsenic acid, the distilled liquor will have no blue colour. 739 Blue aquafortis.

Nitrous Acid COMBINED,

I. *With Vegetable fixed Alkali.* This salt, combined with the nitrous acid to the point of saturation, regenerates nitre. It is observable, however, according to Neumann, that there is always some dissimilarity between the original and regenerated nitre, unless quicklime is added. The regenerated salt, he says, always corrodes tin, which the original nitre does not; owing probably to a quantity of phlogisticated acid remaining in it. Boiling with quicklime deprives it of this quality, and makes it exactly the same with original nitre. 740 Salt-petre.

II. *With Fossile alkali.* The neutral salt arising from a combination of the nitrous acid and fossile alkali is somewhat different from common nitre; being more difficult to crystallize, inclining to deliquate in the air, and shooting into crystals of a cubical form, whence it gets the name of *cubic nitre*. Its qualities are found somewhat inferior to the common nitre; and therefore it is never made, unless by accident, or for experiments. 741 Cubic nitre.

Nitre is one of the most fusible salts. It is liquefied in a heat much less than what is necessary to make it red; and thus remain in tranquil fusion, without swelling. If nitre thus melted be left to cool and fix, whe- 742 Fusibility.

Nitrous acid and its combinations.

whether it has been made red-hot or not in the fuſion, it coagulates into a white, ſemi-transparent, ſolid maſs, called *mineral cryſtal*, having all the properties of nitre itſelf. By this fuſion, Mr Beaumé obſerves that nitre loſes very little, if any, of the water contained in its cryſtals, ſince the weight of mineral cryſtal is nearly the ſame with that of the nitre employed.

When nitre is kept in fuſion with a moderate heat, and at the ſame time does not touch any inflammable matter, nor even flame, it remains in that ſtate without ſuffering any very ſenſible alteration; but if it is long kept in fuſion with a ſtrong fire, part of the acid is deſtroyed by the phlogiſton which penetrates the crucible; and hence the nitre becomes more and more alkaline.

743 Uſes.

Nitre is of very extenſive uſe in different arts; being the principal ingredient in gun-powder; and ſerving as an excellent flux to other matters; whence its uſe in glaſs making. (See Glass.) It is alſo poſſeſſed of a conſiderable antiſeptic power; whence its uſe in preſerving meat, to which it communicates a red colour. In medicine, nitre is uſed as a diuretic, ſedative, and cooler; but very often ſits uneaſy on the ſtomach. The reſemblance of the cryſtals of nitre to thoſe of Glauber's ſalt has ſometimes been the occaſion of dangerous miſtakes. Dr Alexander mentions a ſwelling over the whole body of a woman, occaſioned by her taking a ſolution of nitre inſtead of Glauber's ſalt. Two miſtakes of the ſame kind we have alſo known. In one an ounce, and in the other upwards of two ounces, of nitre were ſwallowed. The ſymptoms occaſioned were univerſal coldneſs and ſhiverlng, extreme debility and ſickneſs at ſtomach, cold ſweats and faintings. Neither of the caſes proved mortal. The cure was effected by cordials and corroborants.

744 Sal prunella.

A proceſs has obtained a place in the diſpenſatories for a ſuppoſed purification of nitre by means of flower of brimſtone. A pound of ſalt-petre is to be melted in a crucible, or ſmall iron veſſel; and an ounce of flowers of ſulphur thrown upon it, by ſmall quantities at a time: a violent deflagration enſues on each addition; and after the whole is put in, the ſalt is poured out in moulds, and then called *ſal prunella*. It has been diſputed whether the nitre was at all depurated by this proceſs; Dr Lewis thinks it is not. From our own experience, however, we can affirm, that by this means a ſediment falls to the bottom, which carries with it any impurities that may have been in the nitre, and leaves the fluid ſalt clear and tranſparent as water. This precipitate is probably no other than a vitriolated tartar formed by the union of the ſulphureous acid and alkali of the nitre, which being leſs fuſible than the nitre, ſubſides in a ſolid form and clarifies it.

745 Nitrous ammoniac.

III. *With Volatile Alkali.* The nitrous acid ſeems peculiarly adapted to an union with volatile alkali; ſaturating as much, or rather more of it than the ſtrongeſt vitriolic acid is capable of doing. The product is a very beautiful ſalt, called *volatile nitre*, or *nitrous ſal ammoniac*. It very readily diſſolves, not only in water, but in ſpirit of wine, which diſtinguiſhes it from the vitriolic and common kind of ſal ammoniac. It alſo requires leſs heat for its ſublimation: indeed care muſt be taken not to apply too great a heat for this purpoſe, as the nitrous ſal ammoniac has the property of deflagrating by itſelf without any addition of inflammable matter; and this it does more or leſs readily, as the volatile alkali with which it was made was more or leſs impure and oily.

746 Dr Ward's white drop.

The medical virtues of this kind of nitre have not been inquired into. It ſeems to have made the principal ingredient in the famous Dr Ward's white drop, which was celebrated as an antiſcorbutic; with what juſtice thoſe who have tried it muſt determine.

747 Calcareous nitre.

IV. *With Calcareous Earths.* Theſe the nitrous acid diſſolves into a tranſparent colourleſs liquor; but for this purpoſe it muſt be very much diluted, or the ſolution will have a gelatinous conſiſtence. This compound is not applicable to any uſeful purpoſe. It has a very acrid taſte; and, if inſpiſſated, attracts moiſture from the air. If it is totally dried, it then reſembles an earthy matter, which deflagrates very weakly. By diſtillation in a retort, almoſt all the acid may be expelled, and what little remains flies off in an open fire.

748 Nitrous acid decompoſed.

Mr Pott, who has particularly examined the combination of nitrous acid with quicklime, ſays that the acid ſuffered remarkable alterations by diſtillation from quicklime, and repeated cohobations upon it. By theſe experiments he obtained a ſalt more ſenſibly ſuſceptible of cryſtallization and detonation, than what can be obtained by a ſingle combination. From his experiments it would ſeem, that nitrous acid, by this treatment with quicklime, was capable of being entirely decompoſed.

If a ſolution of chalk in the nitrous acid be evaporated to dryneſs, and then gently calcined, it acquires the property of ſhining in the dark, after having been expoſed to the ſun's rays, or even to the light of a candle. This ſubſtance, from its inventor, is called *Baldwin's phoſphorus*; or, from its being neceſſary to keep it in a glaſs hermetically ſealed, *phoſphorus hermeticus*. (See Earths). 749 Phoſphorus.

V. *With Argillaceous Earths and Magneſia.* All that is known concerning the combinations of nitrous acid with theſe earths is, that the firſt produce aſtringent, and the ſecond purgative compounds, ſimilar to alum and Epſom ſalt, and which are not ſuſceptible of cryſtallization.

750 Gold.

VI. *With Gold.*—Till very lately it has been the opinion of chemiſts, that the nitrous acid by itſelf was incapable of acting upon this metal.—Dr Brandt, however, produced before the Swediſh academy of ſciences, a ſolution of gold in the nitrous acid, obtained in parting, by that acid, a mixture of gold and ſilver. —The mixed metal was boiled with aquafortis in a glaſs body fitted with a head and receiver, the liquor poured off, and the coction repeated with freſh parcels of ſtronger and ſtronger nitrous ſpirit, till all the ſilver was judged to be extracted. The laſt parcel was boiled down till the matter at the bottom looked like a dry ſalt; on boiling this in freſh aquafortis in cloſe veſſels, as before, a part of the gold was diſſolved, and the liquor tinged yellow. But though gold is by this means truly ſoluble in the nitrous acid, the union is extremely ſlight; the gold being not only precipitated on the addition of ſilver, but likewiſe ſpontaneouſly on expoſure to the air.—Dr Lewis very juſtly obſerves, that this ſolution may have been often made unknown

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unknown to the chemist who did so; and probably occasioned the mistakes which some have fallen into, who thought that they were in possession of aquafortis capable of transmuting silver into gold. Notwithstanding these authorities, Mr Kirwan is of opinion that the nitrous acid is in no case able to dissolve gold; the metal being only intimately mixed or diffused through it.

751 Silver.

II. *With Silver.*—Pure spirit of nitre will dissolve its own weight of silver; and shoots with it into fine white crystals of a triangular form, consisting of very thin plates joined closely one upon another. These crystals are somewhat deliquescent; of an extremely bitter, pungent, and nauseous taste; and, if taken internally, are highly corrosive and poisonous. They melt in a

752 Lunar caustic.

small heat, and form, on cooling, a dark-coloured mass still more corrosive, called *lunar caustic*, or *lapis infernalis*. They readily dissolve in water; and, by the assistance of warmth, in spirit of wine. In the *Acta Naturæ Curiosorum*, tom. vi. there is a remarkable history of silver being volatilized by its combination with the nitrous acid. Four ounces of silver being dissolved in aquafortis, and the solution set to distil in an earthen retort, a white transparent butter rose into the neck, and nothing remaining behind; by degrees the butter liquefied, and passed down into the phlegm in the receiver. The whole being now poured back into the retort, the silver arose again along with the acid. The volatilization being attributed to the liquor having stood in a laboratory where charcoal was bringing in, the experiment was repeated with a fresh solution of silver, and a little powdered charcoal, with the same event.

753 Colours produced by solution of silver.

Solution of silver in the nitrous acid stains hair, bones, and other solid parts of animals, and different kinds of wood, of all the intermediate shades from a light brown to a deep and lasting black. The liquors commonly sold for staining hair brown or black, are no other than solutions of silver in aquafortis, so far diluted in water as not sensibly to corrode the hair.

It gives a permanent stain likewise to sundry stones; not only to those of the softer kind, as marble, but to some of considerable hardness, as agates and jaspers. The solution for this purpose should be fully saturated with the metal; and the stone, after the liquor has been applied, exposed for some time to the sun. M. du Fay observes (in a paper on this subject in the French memoirs for 1728), that if the solution be repeatedly applied, it will penetrate into the whitish agate, or chalcedony, about one-twelfth of an inch: that the tincture does not prove uniform, on account of the veins in the stone: that the colours, thus communicated by art, are readily distinguished from the natural, by disappearing on laying the stone for a night in aquafortis: that, on exposing it to the sun afterwards for some days, the colour returns: that the solution gave somewhat different tinctures to different stones; to oriental agate, a deeper black than to the common chalcedony; to an agate spotted with yellow, a purple; to the jade stone, a pale brownish; to the common emerald, an opaque black; to common granite, a violet unequally deep; to serpentine stone, an olive; to marble, a reddish, which changed to purple, and fixed in a brown; that on slates, talcs, and amianthus, it had no effect.

If a solution of silver be diluted with pure water, a considerable quantity of pure mercury added, and the whole set by in a cold place; there will form by degrees a precipitation and crystallization resembling a little tree, with its root, trunk and branches, called

754 Arbor Dianæ.

arbor Dianæ, or the *philosophic silver tree*. Another kind of artificial vegetation may be produced by spreading a few drops of solution of silver upon a glass plate, and placing in the middle a small bit of any of the metals that precipitate silver, particularly iron. The silver quickly concretes into curious ramifications all over the plate.

755 Solution of silver decomposed.

Like other metallic solutions, this combination of the nitrous acid with silver is decomposed by fixed and volatile alkalies, calcareous earths, and several metals, (see the *Table* of *Affinities*); but with several peculiar circumstances attending the precipitation. With metals, the silver is readily and copiously thrown down at first, but slowly and difficultly towards the end. The menstruum generally retains some portion of the silver, as the silver almost always does of the metal which precipitated it. For recovering the silver from aquafortis after parting, the refiners employ copper. The solution, diluted with water, is put into a copper vessel, or into a glass one with thin plates of copper, and set into a gentle warmth. The silver begins immediately to separate from the liquor in form of fine grey scales, or powder; a part of the copper being dissolved in its place, so as to tinge the fluid more or less of a bluish green colour. The plates are now and then shaken, that such part of the silver as is deposited upon them may fall off, and settle to the bottom. The digestion is continued till a fresh bright plate, kept for some time in the warm liquor, is no longer observed to contract any powdery matter on the surface; when the liquor is poured off, and the precipitate washed with fresh parcels of boiling water. It is observable, that though the acid in this process saturates itself with the copper, in proportion as it lets go the silver, yet the quantity of copper which it takes up is not near so great as that of silver which it deposits. One drachm of copper will precipitate three of silver, and saturate all the acid that held the three drachms dissolved.

756 Characters curiously marked on the inside of a glass by means of the sun's light.

Calcareous earths, as chalk or quicklime, throw down a part of the silver, but leave a very considerable part suspended in the liquor. If the earth be moistened with the solution into the consistence of a paste, and exposed to the sun, it changes its white colour to a dark purplish black; distinct characters may be exhibited on the matter, by intercepting a part of the sun's light by threads, slit paper, *&c.* placed on the outside of the glass. Culinary fire does not affect its colour: after the mass has been exsiccated by this, it changes as before, on exposure to the sun.

Mild volatile alkaline spirits, added to a solution of silver, precipitate but little, and caustic volatile alkalies none. Pure fixed alkalies, and alkalies rendered caustic by quicklime, throw down the whole. Fixed alkalies impregnated with inflammable matter by calcination with animal coals, occasion at first a considerable precipitation; but if added to a larger quantity, take up a great part of the metal again. Mr Marggraaf relates, that edulcorated calces of silver totally dissolve, both in a lixivium of these alkalies and in volatile

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latile spirits; and that the marine acid precipitates the silver from the volatile, but not from the fixed, alkaline solution. Kunckel reports that the calx precipitated by volatile spirits made with quicklime, fulminates or explodes in the fire; and that by inspissating a solution of pure silver, melting the dry residuum, pouring it on spirit of urine supersaturated with salt, and setting the mixture in a gentle warmth, a blood-red mass is produced, so tough as to admit of being wound about the fingers.

757 Copper.

III. *With Copper.* The nitrous acid very readily dissolves this metal into a green-coloured and very caustic liquor. The solution, if properly evaporated, will crystallize; but the crystals are deliquescent, and therefore difficult to be preserved. The only use of this

758 Verditer.

combination is for the preparation of the pigment called *verditer*. Of this there are two kinds, the blue and green. The blue is by far the brightest colour, and consequently the most valuable. It has been said that this is obtained by precipitating a solution of copper by any calcareous earth; and therefore is sold by the refiners who have large quantities of solution of copper accidentally made. The solution is said to be precipitated by chalk, or whiting; and that the precipitate is the beautiful blue colour called *verditer*. By this method, however, only the green kind can be obtained. The blue we have found to be of a quite different nature, and formed by precipitation with a gentle heat from a solution of copper in volatile alkali. See the article COLOUR-MAKING.

759 Iron.

IV. *With Iron.* On this metal the concentrated nitrous acid acts very violently, and plentifully corrodes, but does not dissolve it; the calx falling almost as fast as dissolved; and when it is once let fall, fresh acid will not take it up again. If the acid was diluted at first, it takes up a considerable porportion, provided the metal be leisurely added. If the solution is performed with extreme slowness, the colour will be green; but if otherwise, of a dark red. It does not crystallize; and, if inspissated to dryness, deliquates in the air.

760 Tin.

V. *With Tin.* Concentrated nitrous acid acts upon tin with great force, but only corrodes the metal into a white indissoluble mass. In order to obtain a perfect solution of tin in the nitrous acid, the metal must be put in by very little at a time, and a diluted aquafortis made use of. This solution has been considerably used in dyeing, and is remarkable for heightening red colours of all kinds; but the solution made with *aqua-regis* is preferable.

761 Lead.

VI. *With Lead.* Proof aquafortis, lowered with an equal quantity of water, dissolves about half its weight of lead. On diluting the solution with a large quantity of water it turns milky, and deposites great part of the metal. The solution shoots, upon exhaling part of the menstruum, into small pyramidal crystals with square bases, of an austere sweet taste.

762 Quicksilver supposed to be extracted from lead.

In the memoirs of the French academy for 1733, there is a particular account of an experiment, in which mercury is said to have been extracted from lead by dissolving in it the nitrous acid. During the dissolution, there fell a precipitate which is plainly proved to be mercury, and was looked upon to be one of the constituent parts of the lead separated by this simple process: it seems probable, however, that the mercury in this case had been contained in the aquafortis; for pure lead dissolved in pure aquafortis gives no such precipitate.

The crystals of lead in the nitrous acid, when thrown into the fire, do not deflagrate as other combinations of this acid with metallic or saline bases; but crackle violently, and fly round, with great danger to the by standers. If they are rubbed into very fine powder, they may then be melted without any danger. By repeated dissolutions in fresh aquafortis, they at last form a thick fluid like oil, which cannot be dried without great difficulty. This composition is not adapted to any particular use, and is a violent poison.

VII. *With Quicksilver.* Aquafortis of such a degree of strength as to take up half its weight of silver, dissolves with ease above equal its weight of mercury into a limpid liquor, intensely corrosive and poisonous, which spontaneously shoots into white crystals. These crystals, or the solution exsiccated, and moderately calcined, assume a sparkling red colour; and are used in medicine as an escharotic, under the name of *red precipitate*. The precipitate has sometimes been given internally, it is said, in very large quantities; even a whole drachm at one dose. But this would seem incredible; and the pesent practice does not countenance the taking of red precipitate inwardly. This solution seems to have been what gave the efficacy to Ward's white drop. 763 Quicksilver. 764 Red precipitate.

When red precipitate is prepared in quantity, it is proper to distil the mercurial solution; because most of the aquafortis may then be saved. It is exceedingly pure, if by purity we mean its being free of any admixture of vitriolic or marine acid; but is considerably tainted with the inflammable principle of the mercury extricated during the dissolution. In consequence of this, it is very volatile and smoking; which has generally, though improperly, been taken as a sign of strength in the nitrous acid.

VIII. *With Bismuth.* This semimetal is very readily acted upon by the nitrous acid. Proof aquafortis dissolves about half its weight of bismuth. If the metal was hastily added, the solution proves of a greenish colour; if otherwise, it is colourless and transparent. Unless the acid was diluted with about an equal quantity of water, a part of the bismuth crystallizes almost as fast as it dissolves. The metal is totally precipitated both by fixed and volatile alkalies. The last, added in greater quantities than are sufficient for precipitation, take it up again. The liquor generally appears greenish; by alternate additions of the alkaline spirit and solution, it becomes bluish or purple. Fixed alkalies calcined with inflammable matter likewise dissolve the bismuth after they have precipitated it. 765 Bismuth.

The only use of this compound is for the precipitate, which is used as a cosmetic, under the name of *magistery of bismuth*. The common way of preparing this is by diluting the solution very largely with water, upon which it turns milky, and a fine white precipitate falls, which is to be well edulcorated with water, and is then employed as a cosmetic both in washes and pomatums. 766 Magistery of bismuth.

Concerning the preparation of this cosmetic, Neumann observes, that there are sundry variations.— "Some (says he) takes aqua-regia for the menstruum; and for the precipitant a solution of sea-salt, alkalies, spirit

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ſpirit of wine, &c. Some mix with the ſolution of biſmuth a ſolution of benzoin in ſpirit of wine, and thus obtain a magiſtery compounded of biſmuth and benzoin. Others add a ſolution of chalk to the metalline ſolution, and precipitate both together by alkalies. I have made trial with a good number of different precipitants; and found, that with common fixed alkali and cauſtic alkali, with watery and vinous alkaline ſpirits, the magiſtery was white, and in conſiderable quantity; the liquor, after the precipitation with volatile ſpirits, appearing blue. That oil of vitriol threw down a white precipitate very copiouſly: but that with ſpirit of ſalt, or ſpirit of vitriol, the precipitate was in very ſmall quantity, in colour like the foregoing; diſtilled vinegar making no precipitation at all. Common rectified ſpirit of wine, and tartarized ſpirit, common water, and lime-water, gave white precipitates. Solutions of nitre, vitriolated tartar, ſal mirabile, alum, borax, common ſalt, ſal ammoniac, the combination of marine acid with calcareous earth, and terra foliata tartari, all precipitated the biſmuth white. With a ſolution of gold in aqua-regia the magiſtery proved grey; with a ſolution of the ſame metal in aqua-regia made with ſpirit of ſalt, the precipitate was likewiſe grey, and in ſmall quantity; with ſolution of copper in aquafortis, white, and in very ſmall quantity, the liquor continuing blue; with ſolution of vitriol of copper, white; with ſolution of mercury ſublimate, white and plentiful; with ſolution of iron in aquafortis, yellowiſh; with ſolution of lead in aquafortis, and of ſugar of lead, white; with ſolution of zinc in aquafortis there was little precipitate; and with ſolutions of ſilver, tin, regulus of antimony, and of mercury, in the ſame acid, none at all."

767 Zinc.

IX. *With Zinc.* Upon this ſemimetal the nitrous acid acts with greater violence than any other, and will forſake any other metallic ſubſtance for it. The whole is very ſoon diſſolved into a tranſparent colourleſs liquor. The calces of flowers of zinc are likewiſe ſoluble in the nitrous acid; but neither the ſolution of the flowers, nor of the metal itſelf, have been yet found applicable to any uſeful purpoſe. Neumann remarks, that on extracting with nitrous acid the ſoluble parts of calamine, which is an ore of zinc, the ſolution, inſpiſſated to dryneſs, left a reddiſh brown maſs, which on digeſtion with ſpirit of wine exploded and burſt the veſſel.

768 Regulus of antimony.

X. *With Regulus of Antimony.* The nitrous acid rather corrodes than diſſolves this ſemimetal. The corroded powder forms a medicine formerly uſed under the name of *bezoar mineral*, but now diſregarded.

769 Regulus of cobalt.

XI. *With Regulus of Cobalt.* This ſemimetal diſſolves readily in the nitrous acid, both in its metallic form and when reduced to a calx. The ſolution is of a red colour. Hence the nitrous acid furniſhes means of diſcovering this ſemimetal in ores after ſtrong calcination; very few other calces being ſoluble in the nitrous acid, and thoſe that are not influencing the colour.

770 Regulus of cobalt, how diſcovered in ores.

XII. *With Nickel.* This ſemimetal is eaſily diſſolved by the nitrous acid into a deep green liquor; but neither this ſolution, nor indeed the ſemimetal of which it is made, has hitherto been found of any uſe.

XIII. *With Arſenic.* This ſubſtance is readily diſſolved by the nitrous acid; which abſtracts the phlogiſton, and leaves the pure arſenical acid behind. See below *Acid of Arſenic.*

Nitrous acid and its combinations.

771 Oils.

XIV. *With Expreſſed Oils.* Theſe, as well as all other fatty or unctuous ſubſtances, are conſiderably thickened and hardened by their union with the nitrous acid. There is only one preparation where this combination is applied to any uſe. It is the *unguentum citrinum* of the ſhops. This is made by adding to ſome quantity of melted hog's-lard a ſolution of quickſilver in the nitrous acid. The acid, though in a diluted ſtate, and combined with mercury, nevertheleſs acts with ſuch force on the lard, as to render the ointment almoſt of the conſiſtence of tallow.

772 Unguentum citrinum.

773 Spirit of wine.

XV. *With Vinous Spirits.* If highly rectified ſpirit of wine and ſtrong ſpirit of nitre are ſuddenly mixed together, the acid inſtantly becomes volatile, and is diſſipated with great heat and effervescence in highly noxious red fumes. If the acid is cautiouſly poured into the ſpirit, in the proportion of five, ſix, or even ten parts of ſpirit to one of acid, and the mixture diſtilled in a glaſs retort ſet in a water-bath, an exceedingly fragrant and volatile ſpirit comes over, uſed in medicine as a diuretic and cooler, under the name of *ſpiritus nitri dulcis.* This liquor is not acid; nor has what remains in the retort any more the characteriſtics of nitrous acid, which ſeems to be entirely decompoſed in this proceſs. (See the following article.)

774 Spiritus nitri dulcis.

775 Nitrous ether.

With the nitrous acid and ſpirit of wine, may alſo be made an exceedingly volatile liquor, called *nitrous ether*, to diſtinguiſh it from the vitriolic abovementioned. The proportions of nitrous acid and ſpirit of wine to each other for nitrous ether, are two of the acid by weight to three of the ſpirit. Dr Black's proceſs for making it is as follows. Take four ounces of ſtrong phlogiſticated nitrous acid; and having cooled it by putting it into a mixture of ſalt and ſnow, or into water cooled very near the freezing point, by putting pieces of ice into it, he puts it into a phial, and pours upon it an equal quantity of water, likewiſe cooled very low, in ſuch a manner that the water may float as much as poſſible on the ſurface of the ſpirit. Six ounces of ſtrong ſpirit of wine are then put in, ſo as to float in like manner on the ſurface of the water; the phial is placed in a veſſel containing cold water: and ſo great is the power of cold in reſtraining the action of bodies, that if the mixture was too cold, no ether would be produced; but at the temperature juſt mentioned, the ether begins to be formed in a few hours, with ſome little effervescence, and an expulſion of a ſmall quantity of nitrous air. We muſt provide for the eſcape of this elaſtic fluid, by having an hole in the cork, or the veſſel would be broken. The whole of the ether will be formed in a few days, and may be ſeparated from the reſt of the liquor by means of a funnel, ſhaped as in Pl. CXXXIV. fig. 9.

776 Woulfe's proceſs for procuring it in large quantities.

To procure the nitrous ether in large quantities, Mr Woulfe recommends the following proceſs. Put into a retort four pounds of nitre, then mix together four pounds of vitriolic acid, and three pounds five ounces of ſpirit of wine. Theſe are poured on the nitre by adding only two ounces at a time: the vitriolic acid acting on the nitre, produces a ſufficient degree of heat; and the acid of the nitre uniting with the

Nitrous acid and its combinations.

the ſpirit, forms a nitrous ether, which flies off from the mixture, and is condenſed in a number of veſſels placed in cold water.—To obtain good nitrous ether readily, and at one diſtillation, Mr Dollfuſs adviſes to diſtil four parts of nitre of manganeſe, four of vitriolic acid, and eight parts of ſpirit of wine.

777 Inquiry into the nature of ether.

Macquer ſuppoſes that ether is the moſt oily part or quinteſſence of ſpirit of wine. But it cannot be proved that ether contains any oil. And, beſides, if this were the caſe, thoſe acids which have the ſtrongeſt attraction for water would produce the greateſt quantity of ether; which is found not to be the caſe: and it is moſt probable that ether is produced by a combination of ſome part of the acid with a portion, particularly the inflammable part, of the ſpirit of wine; and it has been ſhown by chemical experiments, that every kind of ether contains a part of the acid employed. Dr Black himſelf has formed ether without any ſpirit at all, by expoſing nitrous acid highly phlogiſticated for ſome months to the light of the ſun. This was owing to the attraction of the principle of inflammability; which it is well known that light has the power of affording to bodies that attract it with force.

Nitrous Acid DECOMPOSED,

778 Oils fired by ſpirit of nitre.

I. *By Eſſential Oils.* If equal quantities of ſtrong nitrous acid and oil of cloves are poured into the ſame veſſel, the mixture inſtantly takes fire; both acid and oil burning with great fury till only a light ſpongy coal remains. Dr Lewis obſerves, that this experiment does not always ſucceed, and that there are but few oils which can be fired with certainty, without attending to a particular circumſtance firſt diſcovered by M. Rouelle, and communicated in the French Memoirs for the year 1747. "On letting fall into the oil equal its quantity of acid, the mixture effervefces, ſwells, and a light fungous coal ariſes: a little more of the acid poured upon this coal ſets it inſtantly on fire. By this method almoſt all the diſtilled oils may be fired by ſpirit of nitre of moderate ſtrength. Expreſſed oils alſo may be ſet on fire by a mixture of the nitrous acid and oil of vitriol; the uſe of which laſt ſeems to be to abſorb the aqueous humidity of the ſpirit of nitre.

779 Nitre alkalized.

II. *By Charcoal.* By this ſubſtance the nitrous acid cannot be conveniently decompoſed, unleſs it is combined with an alkaline or metallic baſe. For the purpoſe of decompoſing the acid, common ſaltpetre is moſt convenient. The proportions recommended by Dr Lewis for alkaliſating nitre, are four ounces of the ſalt to five drachms of powdered charcoal. If theſe are carefully mixed, and injected by little and little into a tubulated retort made red hot, and fitted with a large receiver and a number of adopters, a violent deflagration will enſue on every addition, attended with a great quantity of air, and ſome vapours which will circulate for ſome time, and then condenſe in the veſſels. This

780 Clyſſus of nitre.

liquor is called *clyſſus of nitre.* If ſulphur is uſed inſtead of nitre, the clyſſus is of a different kind, conſiſting of a mixture of the nitrous and vitriolic acids. The reſiduum, when charcoal is uſed, is a very ſtrong and pure alkali; with ſulphur it is vitriolated tartar. To prevent the loſs occaſioned by the violent deflagration, when this operation is performed in open veſſels, Dr Black recommends to have the materials ſomewhat moiſt.

III. *By Vinous Spirits.* In the proceſs already mentioned for making *ſpiritus nitri dulcis*, a total decompoſition of the acid ſeems to take place: for neither the dulcified ſpirit itſelf, nor the acid matter left in the retort, ſhow any ſigns of deflagration with inflammable matters, which is the peculiar characteriſtic of nitrous acid.

Marine acid and its combinations.

781 Reſiduum of ſpiritus nitri dulcis analized by Mr Pott.

Mr Pott has given an analyſis of the oleaginous reſiduum of the diſtillation. Diſtilled by a ſtronger fire, it gave over a yellow, acid, ſlightly empyreumatic ſpirit; which being ſaturated with fixed alkali, the liquor evaporated, and the dry neutral ſalt laid on burning coals, did not deflagrate. After this ſpirit aroſe a red empyreumatic oil; and in the bottom of the retort was left a ſhining black maſs like ſoot; which, burnt in a crucible, left a white fixed earth, convertible by a vehement fire into glaſs. Another parcel of the above reſiduum was evaporated to the conſiſtence of pitch. In this ſtate it gave a yellow tincture to ſpirit of wine, flamed vividly and quietly on burning coals, and at laſt ſwelled up like bitumen. Another portion was ſaturated with alkaline ley, with which it immediately effervefced, and then evaporated as the former. It gave, as before, a yellow colour to rectified ſpirit of wine, and a much deeper yellow to dulcified ſpirit of nitre; and in the fire diſcovered no footſtep of detonation. M. Macquer ſuppoſes this acid to have been not the nitrous, but the acetous, which enters into the compoſition of the ſpirit of wine; and his conjecture is now confirmed by late experiments.

§ 3. *Of the MARINE Acid and its Combinations.*

782 Marine acid.

THIS acid is never, at leaſt very rarely, found but in a ſtate of ſaturation with the mineral alkali; in which caſe it forms the common ſalt uſed in food. Almoſt the only exception to this is human urine, and perhaps that of ſome other animals; for there the marine acid is found ſaturated, not with the mineral, but the common vegetable, fixed alkali. From being found in ſuch plenty in the waters of the ocean, it has the name of *marine acid.*

783 Marine acid thought to be the ſame with the vitriolic.

It is commonly thought that this acid is no other than the vitriolic, ſomehow or other diſguiſed by the inflammable principle; to which ſome have added another, called by them a *mercurial earth.*

The reaſons given for this ſuppoſition, however, are but very ſlight, conſiſting chiefly in the reſemblance between the volatile vitriolic acid and the marine, both in the white colour of their vapours, and likewiſe the great volatility of both. As to the exiſtence of that principle called a mercurial earth, it hath never been proved; and, till that time, can never be allowed to be an ingredient in the compoſition of any ſubſtance whatever. As we do not remember to have read of any experiments where the marine acid was directly produced from that of vitriol, we ſhall content ourſelves with relating one very remarkable fact which happened to fall under our own obſervation.

784 A tranſmutation.

As vitriolated tartar, or Glauber's ſalt, when fuſed with charcoal duſt, is converted into an hepar ſulphuris, attempts have been made on this principle to ſeparate the pure alkali from the reſiduum of Glauber's ſpirit of nitre and ſpirit of ſalt. In an attempt of this kind, which, by the bye, proved unſucceſsful, as all others of the ſame kind muſt do, 30 or 40 pounds

Marine acid and its combination.

pounds of the mafs for Glauber's falt were fufed in a ftrong iron pot, with a fufficient quantity of common coal powdered and fifted. As the quantity of powdered coal was pretty large, the mafs was thereby hindered from flowing into thin fufion; and, that the whole might be perfectly alkalifated, it was frequently ftirred up with an iron ladle, and kept very intenfely heated for fome hours. The mafs was now taken out by means of an iron ladle, and laid on a flat ftone; and, as it was but half fluid, every ladleful concreted into a black irregular faline mafs, which had the appearance of a cinder: but which, however, confifted of an hepar fulphuris mixed with fome coal-duft. As there was a confiderable quantity of this matter, and the ladlefuls were thrown at random above one another, it fo happened, that between two or three of the pieces, a kind of chimney was formed, fo that there being a fmall draught of air through the interftices, and the maffes containing a quantity of coal-duft, the internal parts were in a ftate of ignition, while the external were quite cold. From thefe ignited places a white fume arofe; which being collected on the colder maffes, affumed the form of white flowers. Thefe were found to be genuine fal ammoniac, compofed of a volatile alkali and marine acid; both of which we have the greateft reafon to think were produced at that very time, and that a double tranfmutation took place; namely, of the vitriolic acid into the marine, and of the fixed alkali into the volatile. Our reafons for being of this opinion are, 1. That the matter had been fubjected to fuch an extreme and long continued heat, that, had any fal ammoniac been pre exiftent in the mixture, it muft have certainly been diffipated, as this falt always fublimes with a degree of heat below ignition. 2. Though the matter was taken out of the pot of a very intenfe red heat, fo that the faline part was evidently melted, yet no ammoniacal fume iffued from it at that time, nor till the maffes had been for fome time expofed to the air, and were become cool, excepting only thofe interftices where the air kept up a burning heat, by a fmall draught being formed from the fituation of the faline maffes. 3. In thofe ignited places, when cool, the fixed falt was entirely decompofed, neither alkaline falt, Glauber's falt, fixed alkali, nor fulphur remaining; but the whole was confumed to a kind of ferruginous afhes. We are therefore of opinion, that the marine acid and volatile alkali are, in fome cafes, mere creatures of the fire, and moft commonly produced at the fame time, from the flow combuftion of mineral fubftances. Hence, where heaps of hot cinders are thrown out, fmall quantities of the true fal ammoniac are always formed, when the ignited ones happen to fall in fuch a manner as to occafion a fmall draught of air through them.

785
Dr Prieftley's obfervations on marine acid.

The marine acid, or fpirit of falt, is weaker than either the vitriolic or nitrous; though Dr Prieftley hath obferved, that, when concentrated to the utmoft degree, in which ftate it was perfectly invifible and elaftic as air, it was then able to feparate the nitrous acid from an alkali. In fome other cafes, too, it appears not only ftronger than the nitrous, but even than the vitriolic; of which we fhall take notice in courfe. —Mr Berthollet fays, that he has been able alfo to procure the marine acid in a folid ftate, by diftilling it in Mr Woulfe's apparatus, kept perfectly cool with ice.

Marine acid and its combinations.

The yellow colour of the marine acid is fometimes owing to iron, which may be precipitated from it by means of an alkali. In certain cafes, however, it is obferved to have a much darker and nearly a brown colour, without containing the fmalleft particle of this metal.—Mr Dollfufs is of opinion, that the yellow colour of the marine acid is owing to a portion of dephlogifticated air which it generally contains. A pretty ftrong proof that it emits this kind of air indeed is, that a candle will burn longer in a bottle containing fome marine acid, than it will in an equal quantity of common air.

I. To procure the Marine Acid by means of the *Vitriolic.*

786
Spirit of fea-falt.

Put any quantity of fea-falt into a tubulated glafs-retort, to which a large receiver is firmly luted, having a quantity of water in it, more or lefs as you want your fpirit of falt to be more or lefs ftrong. Having placed your retort in a fand-bath, take of concentrated oil of vitriol half as much as you put falt into the retort. Through the aperture in the upper part of the retort, pour a fmall quantity of the vitriolic acid; a violent effervefcence will immediately arife, and white vapours will afcend, and come over into the receiver. Thefe vapours are the marine acid in its moft concentrated ftate; and, as they are very greedy of moifture, they will unite with the water in a very fhort time, unlefs too much oil of vitriol is put in at once; in which cafe, part of them will be diffipated through the fmall hole in the receiver. When you perceive the firft fumes condenfed, add a little more oil of vitriol, taking care to ftop the aperture of the retort as foon as you drop in the vitriolic acid, that the marine acid may not efcape. Continue this by intervals, till your acid is all put in; and then make a very gentle fire, that the retort may be no warmer than the hand can bear. This degree of heat muft be continued a long time, otherwife very much of the acid will be loft. To perform this operation perfectly, no more acid fhould be forced over, than what the water in the receiver can take up; and by this means the operator's patience will be rewarded with a vaftly larger produce of acid than can be procured by hafty diftillation. When the vapours become a little more fixed, a greater heat is neceffary, but nothing equal to what the nitrous acid requires. For diftilling fpirit of falt, Mr Wiegleb recommends four pounds of oil of vitriol to fix of common falt.—It may alfo be obtained from the bittern remaining after the cryftallization of common falt, by adding one pound of oil of vitriol to five of bittern. It may even be obtained from this liquid by fimple diftillation without any additional acid; but a violent fire will then be neceffary, and it is almoft impoffible to prevent the liquor from fwelling and running over the neck of the retort in the beginning of the procefs.

787
Why diftillation of fea-falt with copperas does not fucceed.

The marine acid cannot be procured by means of combinations of the vitriolic acid with metallic and earthy bafes, as the nitrous is; for though, by means of calcined vitriol, for inftance, the marine acid is effectually expelled from its alkaline bafis, yet it immediately combines with the calx of iron left by the vitriolic acid, and not only adheres obftinately, but even fublimes the metal; fo that what little fpirit can be ob-

Marine acid and its combinations.

obtained, is never pure. This inconvenience is not so great when uncalcined copperas is made use of: for the marine acid has a very strong attraction to water; which partly dissolves its union with the metalline calx. If gypsum is used, instead of calcined vitriol, not a drop of spirit will be obtained. Alum and sal catharticus amarus answer better.

II. To procure the Marine Acid by means of the *Nitrous.*

788 Aqua-regis.

Take equal quantities of sea-salt and Glauber's spirit of nitre; put the salt into a retort, and pour on it the nitrous acid; let them stand for 10 or 12 hours; then distil with a gentle heat; an acid liquor will come over, which is a compound of the nitrous and marine acids, called *aqua-regis*. When the distillation is finished, and the vessels cooled, pour back the distilled liquor on the mass which is left on the retort, and distil again: the second produce will be more of the nature of spirit of sea-salt than the former. Continue to do this, pouring the distilled liquor either on the mass left in the retort, or upon fresh sea-salt, till you observe that no nitrous acid arises. No experiments have been made on this spirit of salt, by which we can judge whether it is different from that procured by the vitriolic acid or not.

III. To procure the Marine Acid, by distilling Salt *per se.*

789 Spirit of salt *per se.*

Put into a retort any quantity of common salt which has not been dried, and distil in a sand-heat till nothing more will come over. In the receiver you will have a liquor considerably more acid than vinegar, in weight about the fourth part of the salt employed. On the dry salt left in the retort, pour some water, somewhat less in quantity than the liquor which came over. Let it stand till the salt has thoroughly imbibed the moisture, and then distil again. You will again have an acid, but weaker than the former. Repeat this six or seven times; after which you will obtain no more marine acid in this way. It has been thought that sea-salt was capable of total decomposition by means of moisture alone; but that is found to be a mistake. The reason of any acid being procurable in this way, is the impurity of the common salt, which is always mixed with a quantity of sal catharticus amarus, and of marine acid combined with magnesia, from which last it is separable by moisture. If a pure salt be formed by combining marine acid with salt of soda, no spirit will be obtained.

IV. To dephlogisticate the Marine Acid.

790 Marine acid dephlogisticated by that of nitre or by manganese.

The marine acid, when mixed either with that of nitre or with manganese, loses that peculiar smell by which it is usually distinguished, and acquires one much more volatile and suffocating. When mixed with the former, the compound is called *aqua-regia*; when subjected to the action of manganese, the product is called *dephlogisticated spirit of salt.* The method of procuring this acid recommended by Mr Scheele is as follows:

791 Scheele's method of dephlogisticating it by manganese.

Mix common muriatic acid in any quantity with levigated manganese in a glass retort; to which lute on with blotting paper a receiver capable of containing about 12 ounces of water. Put about two drachms of liquid into it; and in about a quarter of an hour, or somewhat more, a quantity of elastic fluid, which is the true dephlogisticated spirit of salt, will pass over, and communicate a yellow colour to the air in the receiver; after which the latter is to be separated from the retort. If the paper has been closely applied, a quantity of the air will now rush out with some violence; a cork must therefore instantly be put into it, and another receiver applied, having in like manner two drachms of water in it, which will also be filled in a short time; and thus may several phials full of this aerial acid be procured in a short time. Care should be taken, that the retort be placed in such a manner as that any drops of liquid which chance to arise may fall down again into it. The water put into the receivers seems to condense the vapours of the marine acid; and it is most proper to use small receivers, on account of the great quantity of vapour which is lost at every operation.

792 Properties of dephlogisticated spirit of salt.

The effects of this dephlogisticated marine acid, which can scarcely be condensed into a liquid, are, 1. The lute is corroded in distillation, and the corks become yellow, as from aquafortis. 2. Paper coloured with lacmus becomes nearly white, as well as all vegetable red, blue, and yellow flowers; and the same change is likewise produced upon the green colour of vegetables; nor can any of these colours be recovered either by alkalies or acids. 3. Expressed oils and animal fats, exposed to the vapour, become as tenacious as turpentine. 4. Cinnabar grew white on the surface; and when it was washed, a pure solution of corrosive sublimate was obtained; but sulphur was not changed. 5. Green vitriol became red and deliquescent; but white and blue vitriol remained unchanged. 6. Iron filings were dissolved; and on evaporating the solution to dryness, common muriatic acid was obtained by distillation with marine acid. 7. In like manner all the metals, even gold itself, were dissolved; and by precipitation with volatile alkali, the solution of gold yielded aurum fulminans. 8. The caustic volatile alkali produced a white cloud, and emitted a number of air-bubbles, which on bursting discharged an elastic vapour. 9. Fixed alkali was changed into common salt, which decrepitated in the fire. 10. Arsenic became deliquescent, insects died, and fire was instantaneously extinguished in the vapour.

793 Mistake of Stahl accounted for.

These phenomena proceed from the strong attraction of dephlogisticated marine acid for the phlogiston it has lost; and which is one of the essential parts of it, without which it can scarce at all be condensed into a liquor. "Perhaps (says Mr Scheele) Stahl obtained such a dephlogisticated muriatic acid by means of iron; and from the yellow colour of the cork was led to suppose that the muriatic acid had been changed into the nitrous. If you make a mixture of manganese, muriatic acid, or diluted vitriolic acid, and alcohol; and after some days digestion distil it by a gentle fire, no effervescence ensues: but the spirit of wine goes over; and, what is very remarkable, has a strong smell of nitrous ether.

2d 793 New salt resembling nitre by Mr Berthollet.

A new salt has been produced by Mr Berthollet from the union of dephlogisticated spirit of salt with vegetable alkali. This appears to be of the nitrous kind, as having a cool taste and detonating strongly in the fire. The compound was in very small quantity, and seemed to require more pure air for its composition than an equal bulk of acid. The greatest part of the salt produced was the common salt of Sylvius, or digestive salt, formed by a combination of the phlogisticated marine

Marine acid and its combinations.

rine acid with alkali. Six parts of the dephlogisticated acid are required to give their air to one of the salt. When the fixed alkali is employed, some of the dephlogisticated acid escapes with the pure air; and in general, when not exposed to a bright heat, the salt we speak of is formed. Some of the dephlogisticated acid remains in its proper form after the salt is made, and may be separated by the volatile alkali. It is to be observed, that if the caustic alkali be employed, and the solution much concentrated, even though not under the influence of a bright light (for it is the light which produces the extrication of the dephlogisticated air*), a great effervescence will ensue, and a quantity of dephlogisticated air escape; whence of consequence, little salt can be obtained.

* See *Aërology*, n° 36, *et seq.*

This salt is soluble in greater quantity in hot than in cold water; and not only detonates like nitre, but with much greater violence. The reason is, that, like nitre, it not only contains dephlogisticated air, but has it in greater quantity; an hundred grains of salt giving 75 of air. Attempts have been made to procure gunpowder by means of this salt, but as yet they have been attended with little success.

The other properties of this salt as yet discovered are, that it shoots into rhomboidal crystals; it does not precipitate mercury, silver, or lead, from their solutions in nitrous acid; and it gives out its air again in such a pure state as scarcely to be paralleled in any other substance.

With the mineral alkali the dephlogisticated acid forms a deliquescent salt, soluble in spirit of wine; and which, even in a fluid state, detonates with burning charcoal. With lime, when so far quenched that the air in its interstices is separated, the dephlogisticated acid unites but weakly. It may be recovered from the lime, however, provided the light be obscure, with very little loss, and almost unchanged.

Marine Acid COMBINED,

794 Sal digestivus sylvii.

I. *With Vegetable Fixed Alkali.* This combination is accidentally formed after the distillation of volatile salts, by means of salt of tartar (see *Alkaline Salts).* It was formerly known by the name of *sal digestivus Sylvii;* and a process for making it was inserted in the dispensatories, under the name of *spiritus salis marini coagulatus;* but as it has been found to possess no virtues superior, or even equal, to common salt, it is fallen into disuse.

The crystals of this kind of salt are not cubical, like those of common salt, but parallelopipeds, and if thrown into the fire crack and leap about with violence. They are soluble in greater quantity by hot water than cold; and therefore are crystallized by evaporating the solution to a pellicle, and then letting it cool.—It is very remarkable, that though by a direct combination of vitriolic acid with vegetable fixed alkali, the salt called *vitriolated tartar* is formed; yet if this alkali is once saturated with spirit of salt, so as to form a *sal digestivus,* upon the decomposition of this salt by means of oil of vitriol, the residuum of the distillation will not be a vitriolated tartar, but a salt easily soluble in water, and which bears a strong resemblance to Glauber's salt. Whether, by means of spirit of sea-salt, the vegetable alkali could be converted into the mineral, or salt of soda, is a question well worthy of being solved.

II. *With Mineral Alkali.* This combination is the common alimentary salt, and is never made but for experiment's sake; as the marine acid cannot be had but from sea-salt. For the extraction of this salt from sea-water, see the article SALT.

795 Sal ammoniac.

III. *With Volatile Alkali.* The produce of this combination is the common sal ammoniac, which is used in different arts, and which has the property of making tin unite very readily with iron and copper, so is much used by coppersmiths and in the manufactory of tinned iron.

Sal ammoniac is usually sold in large semi-transparent cakes, which are again capable of being sublimed into masses of the like kind. If they are dissolved in water, the salt very easily shoots into small crystals like feathers. Exposed to a moist air, it deliquates. It is one of the salts which produces the most cold by its solution; so as to sink the thermometer 18 or 20 degrees, or more, according to the temperature of the atmosphere. According to Mr Gellert, a solution of sal ammoniac has the property of dissolving resins. According to Neumann, the volatility of sal ammoniac is so much diminished by repeated sublimations, that at last it remains half fluid in the bottom of the sublimeing vessel. In its natural state, it sublimes with a degree of heat necessary to melt lead. Pott says, that a small quantity of sal ammoniac may be produced by distilling sea-salt with charcoal, or with alum, or by distilling marine acid with Armenian bole. The same author affirms, that the inflammability of sulphur is destroyed by subliming it with twice its quantity of sal ammoniac.

796 How made.

The method of making this salt was long unknown; and it was imported from Egypt, where it was said to be prepared by sublimation from soot alone, or from a mixture of sea-salt, urine, and soot. That it should be produced from soot alone is very improbable; and the other method, from the known principles of chemistry, is absolutely impossible. The composition of this salt, however, being once known, there remained no other desideratum than a method of procuring those competent parts of sal ammoniac sufficiently cheap, so as to afford sal ammoniac made in Britain at a price equally low with what was imported. The volatile alkali is to be procured in plenty from animal substances or from soot; and the low price of the vitriolic acid made from sulphur affords an easy method of decomposing sea-salt, and obtaining its acid at a low rate. A sal ammoniac work has, accordingly, been established for several years past in Edinburgh; the principal material made choice of for procuring the volatile alkali is soot; and though no persons are admitted to see the work, the large quantities of oil of vitriol brought into it, and the quantities of genuine *sal mirabile* which are there made, evidently show that the process for making sal ammoniac also produces Glauber's salt, by the decomposition of common salt by means of vitriolic acid. The method of conducting the process is unknown; but it is plain that there can be no other difficulty than what arises from the volatility of the vapours of the alkali and of the marine acid. In the common way of distilling those substances, a great part of both is lost; and if it is attempted to make sal ammoniac by combining these two when distilled by the common apparatus, the produce

Marine acid and its combinations.

duce will not pay the coſt; a little ingenuity, however, will eaſily ſuggeſt different forms and materials for diſtilling-veſſels, by which the marine acid and volatile alkali may be united without loſing a particle of either.

If a ſolution of vitriolic or Glauber's ſecret ſal ammoniac is mixed with ſea-ſalt, the vitriolic acid ſeizes the alkaline baſis of the ſea-ſalt, and expels the marine acid; which immediately unites with the volatile alkali left by the vitriolic acid, and forms a true ſal ammoniac. If this ſolution is now evaporated to dryneſs, and the ſaline maſs ſublimed, the ſal ammoniac riſes, and leaves a combination of vitriolic acid and mineral alkali at the bottom. This fixed maſs being diſſolved, filtered, and evaporated, affords Glauber's ſalts. This has ſometimes been thought a preferable method of making ſal ammoniac, as the trouble of diſtilling the marine acid was thereby prevented; but it is found vaſtly inconvenient on another account, namely, that when ſal ammoniac is mixed with any fixed ſalt, it is always more difficult of ſublimation, and a part of it even remains entirely fixed, or is deſtroyed. The maſs of Glauber's ſalt alſo, by reaſon of the inflammable and oily matter contained in impure volatile alkalies, is partly changed into a ſulphureous maſs, ſo that the ſolution refuſes to cryſtallize; at leaſt the operation is

797 attended with intolerable trouble

Fixed ſal ammoniac.

IV. *With Earths.* The combinations of this acid with earths of any kind have never been found applicable to any purpoſe, and therefore they are ſeldom made or inquired into. The combination with calcareous earth is indeed pretty frequently made accidentally, in

798 the diſtillation of volatile alkali from ſal ammoniac

Phoſphorus.

by means of chalk or quicklime. When melted in a crucible and cooled, it appears luminous when ſtruck, and has been called *phoſphorus ſcintillans*. See

799 EARTHS.

Solution of gold in ſpirit of ſalt.

V. *With Gold.* The marine acid has no action on gold in its metallic ſtate, in whatever manner the acid be applied; but if the metal is previouſly attenuated, or reduced to a calx, either by precipitation from aqua-regis or by calcination in mixture with calcinable metals, this acid will then perfectly diſſolve, and keep it permanently ſuſpended. Gold, precipitated from aqua-regis by fixed alkalies, and edulcorated by repeated ablutions, may be diſſolved even in a very weak ſpirit of ſalt by moderate digeſtion. This ſolution appears of the ſame yellow colour as that made in aqua-regis; gives the purple ſtain to the ſkin, feathers, bones, and other ſolid parts of animals; the ſame violet ſtain to marble; and ſtrikes the ſame red colour with tin. Even when common aqua-regia is made uſe of for the menſtruum, it ſeems to be chiefly by the marine acid in that compound liquor that the gold is held in ſolution. In diſtillation the nitrous acid ariſes, and the marine acid remains combined with the gold in a blood-red maſs, ſoluble, like moſt of the combinations of metallic bodies with this acid, in ſpirit of wine. If, towards the end of the diſtillation, the fire is haſtily raiſed, part of the gold diſtils in a high ſaffron-coloured liquor; and part ſublimes into the neck of the retort in cluſters of long ſlender cryſtals of a deep red colour, fuſible in a ſmall heat, deliquating in the air, and eaſily ſoluble in water. By repetitions of this proceſs the whole of the gold may be elevated, except a ſmall quantity of white powder whoſe nature is not known. —This red ſublimate of gold is ſaid to be eaſily fuſible with the heat of one's hand, and to be ſhown by the Papiſts for the blood of St Januarius; the ſublimate contained in a phial, being warmed by the hands of the prieſts who hold it, conſtitutes the miracle of that 800

Blood of St Januarius.

ſaint's blood melting on his birth-day.

801

Silver.

VI. *With Silver.* Strong ſpirit of ſalt corrodes leaf-ſilver into a white powder, but has no effect on filings or larger maſſes of the metal. If applied in the form of vapour to maſſes of ſilver, and ſtrongly heated at the ſame time, it readily corrodes them. Thus, if filings, grains, or plates, of ſilver are mixed with about twice their weight of mercury ſublimate, and expoſed to a moderate fire, in a retort, or other diſtilling veſſel, a part of the marine acid in the ſublimate will be ſeparated and unite with the ſilver, leaving the mercury to ariſe in the form of mercurius dulcis. Marine acid is commonly ſuppoſed to be incapable of diſſolving ſilver into a liquid ſtate; but Henckel relates, that if red ſilver ore, which conſiſts of ſilver intimately mixed with red arſenic, be digeſted in ſpirit of ſalt, the ſilver will be extracted and kept permanently diſſolved. 802

Luna cornea.

The combination of marine acid with ſilver is called *luna cornea.* The moſt ready way of preparing it is by diſſolving ſilver in the nitrous acid, and then adding ſpirit of ſalt, or a ſolution of ſea-ſalt, when a precipitation inſtantly enſues; the marine acid expels the nitrous, and uniting with the ſilver, falls to the bottom in form of a white powder. The ſame precipitation would take place, if a ſolution of ſilver was made in the vitriolic acid. 803

Its properties.

Luna cornea weighs one-fourth more than the ſilver employed; yet, when perfectly waſhed, it is quite inſipid to the taſte. It does not diſſolve in water, ſpirit of wine, aqua-fortis, or aqua-regis; but is in ſome ſmall degree acted upon by the vitriolic acid. It melts in the fire as ſoon as it grows red-hot; and, on cooling, forms a ponderous browniſh maſs, which being caſt into thin plates, becomes ſemitranſparent, and ſomewhat flexible, like horn; whence its name *luna cornea.* A ſtronger fire does not expel the acid from the metal, the whole concrete either ſubliming entire, or paſſing through the crucible. It totally diſſolves in volatile alkaline ſpirits without any ſeparation of the metal. Expoſed to the fire in a cloſe copper veſſel, it penetrates the copper, and tinges it throughout of a ſilver colour. Kunckel obſerves, that when carefully prepared, melted in a glaſs veſſel, and ſuffered to cool ſlowly, to prevent its cracking, it proves clear and tranſparent; and may be turned into a lathe and formed into elegant figures. He ſuppoſes this to be the preparation which gave riſe to the notion of malleable glaſs. 804

Copper.

VII. *With Copper.* In the marine acid, copper diſſolves but ſlowly. The ſolution, if made without heat, appears at firſt brown; but, on ſtanding for ſome time, depoſits a white ſediment, and becomes green. On adding freſh copper, it becomes brown again, and now recovers its greenneſs more ſlowly than before. The white ſediment, on being barely melted, proves pure and perfect copper of the ſame colour as at firſt. Copper calcined by fire communicates a reddiſh colour to this acid. 805

Iron.

VIII. *With Iron.* The marine acid acts upon iron

leſs

Marine acid and its combinations.

leſs vehemently than the nitrous, and does not diſſolve ſo much; nevertheleſs, it attacks the metal briſkly, ſo as to raiſe conſiderable heat and effervesſcence, and diſſolve it into a yellow liquor. During the ſolution, an inflammable vapour ariſes as in the ſolution of this metal by vitriolic acid. This ſolution of iron does not cryſtallize. If it is evaporated, it leaves a greeniſh

806 ſaline maſs, which is ſoluble in ſpirit of wine, and runs
Iron volatilized. in the air into a aſtringent yellow liquor. On diſtillation, ſome of the acid ſeparates, and towards the end of the operation the ſpirit becomes yellow. This is followed by a yellowiſh, or deep reddiſh ſublimate, which gliſtens like the ſcales of fiſhes; leaving behind a ſubſtance which conſiſts of thin, gloſſy plates, like talc.

807
Tinctura martis.

The ſolution of iron in ſpirit of ſalt, with the addition of ſome ſpirit of wine, is uſed in medicine as a corroborant, under the name of *tinctura martis*. The ſublimate of iron is alſo uſed for the ſame purpoſe, and called *ens veneris*, or *flores martiales*. It is commonly directed to be prepared by ſubliming iron filings and ſal ammoniac together. In the proceſs, the

808 ſal ammoniac is partly decompoſed, and a cauſtic al-
Flores martiales. kaline liquor diſtils. Then the undecompoſed ſal ammoniac, and the martial ſublimate abovementioned, ariſe together. The ſublimate has a deeper or lighter yellow colour, according as it contains more or leſs iron. The name *ens veneris* is improper. It was given by Mr Boyle, who diſcovered this medicine. He imagined it to be a preparation of copper, having made uſe of a colcothar of vitriol containing both iron and copper. A me-

2d 808 dicine of this kind was lately ſold with great reputation
Beſtuchef's tincture. on the Continent, under the name of *Beſtuchef's nervous tincture*. It was introduced by M. Beſtuchef Field Marſhal in the Ruſſian ſervice: but not long after it came into vogue in Pruſſia and other northern kingdoms of Europe: it made its appearance alſo in France, under the name of *General de la Motte's golden drops*. This happened through the infidelity of Beſtuchef's operator, who, for a ſum of money, violated the oath of ſecrecy he had taken to Beſtuchef, and diſcovered the ſecret to de la Motte. To the latter it proved a very valuable acquiſition; for he not only procured a patent for it from the king of France in 1730, with the excluſive privilege of ſelling it, but had a handſome penſion ſettled upon him; ſelling his medicine beſides

3d 808 a half a Louis d'or per phial.
Miſtakes concerning it.

The attention of the public was particularly drawn to theſe drops, by their remarkable property of loſing their yellow colour in the ſun, and regaining it in the ſhade, which induced many to believe that they contained gold; and in which opinion they were encouraged by de la Motte. Even chemiſts of no little reputation were deceived by this appearance; and M. Beaumé, imagining he had diſcovered the ſecret, publiſhed a preparation to the world as the true arcanum of la Motte's drops. It conſiſted of a calx of gold precipitated from aqua-regia by means of fixed alkali, and rediſſolved in nitrous acid, to which was added a large quantity of ſpirit of wine. Others, however, who could find nothing but iron by an analyſis

4th 808 of the drops, refuſed their aſſent; and at length, in
True method of preparing it. 1780, M. Beaumé's miſtake was made evident by the publication of the proceſs at the deſire of the empreſs of Ruſſia, who gave 3000 rubles for the receipt. The original *recipe* is perplexed, tedious, and expenſive; but when deprived of its ſuperfluous parts, is nearly as follows. Six pounds of common pyrites and twelve of corroſive ſublimate are to be triturated together, and then ſublimed ſix or eight times till all the mercury is expelled. The reſiduum is to be boiled three times with thrice its quantity of water, and as often filtered, and laſtly, diſtilled to dryneſs. By increaſing the fire, a martial ſalt is at laſt ſublimed into the neck of the retort; to three drachms of which are to be added 12 ounces of highly rectified ſpirit of wine, and the whole expoſed to the rays of the ſun. This is the yellow tincture; but there was alſo a white one, which, however, ſeems to be but of little value. It is made by pouring on the reſiduum of the laſt ſublimation twelve pounds of highly rectified ſpirit of wine, and drawing it off by a gentle diſtillation after a few 5th 808
days digeſtion.—Mr Klaproth imagines, from the fol- Suppoſed to absorb phlogiſton from the ſun's rays.
lowing experiment, that Beſtuchef's tincture abſorbs phlogiſton from the rays of the ſun. He poured a few drops of a ſolution of tartar into two ounces of diſtilled water, and divided this into two parts. Into one glaſs having poured a few drops of the tincture that had not been expoſed to the ſun, the iron was precipitated in the uſual form of a yellow ochre; but on treating in the ſame manner a portion of the tincture that had been expoſed to the ſolar rays, the precipitate fell of a bluiſh green colour. 809

Solution of tin.

IX. *With Tin*. Though the concentrated marine acid has a greater attraction for tin than any other acid, it does not readily diſſolve this metal while the acid is in its liquid ſtate; but may be made to diſſolve it perfectly by the addition of a ſmall quantity of ſpirit of nitre. Neumann obſerves, that an ounce of ſpirit of ſalt, with only a ſcruple of ſpirit of nitre, diſſolved tin perfectly: but on inverting the proportions, and taking a ſcruple of marine acid to an ounce of the nitrous, four ſcruples, or four and an half, of tin, were diſſolved into a thick pap; ſome more of the marine acid being gradually added, the whole was diſſolved into a clear liquor. In making theſe ſolutions, a ſmall quantity of black matter uſually ſubſides.

The ſolution of tin is ſometimes colourleſs; ſometimes of a bluiſh, or yellow colour, according to different circumſtances of the proceſs. It is of the greateſt conſequence in dyeing, by not only heightening the colours, but making them more durable (See Dyeing). It ſhoots into ſmall cryſtals; and, if inſpiſſated, deliquates in the air. 810

Smoking liquor of Libavius.

Marine acid in its concentrated ſtate volatilizes tin, and forms with it a thick liquor, which, from its inventor, is called *ſmoking liquor of Libavius*. To prepare this ſmoking liquor, an amalgam muſt be made of four parts of tin and five of mercury. This amalgam is to be mixed with an equal weight of corroſive mercury, by triturating the whole together in a glaſs mortar. The mixture is then to be put into a glaſs retort, and the diſtillation performed with a fire gradually increaſed. A very ſmoking liquor paſſes into the receiver; and towards the end of the diſtillation, a thick, and even concrete matter. When the operation is finiſhed, the liquor is to be poured quickly into a cryſtal glaſs-bottle, with a glaſs ſtopper. When this bottle is opened, a white, copious, thick, the poignant fume iſſues, which remains long in the air without diſappearing.

The acid in this liquor is far from being ſaturated, and

Marine acid and its combinations.

and is capable of still dissolving much tin in the ordinary way. From this imperfect saturation, together with its concentration, proceeds partly its property of smoking so considerably: nevertheless, some other cause probably concurs to give it this property; for though it smokes infinitely more than the most concentrated spirit of salt, its vapours are, notwithstanding, much less elastic. It has all the other properties of concentrated marine acid when imperfectly saturated with tin. If it is diluted with much water, most of the metal separates in light white flocks. In dyeing, it produces the same effects as solution of tin made in the common way. If the distillation is continued after the smoking liquor of Libavius has come over, the mercury of the corrosive sublimate will then arise in its proper form.

811 Lead.

X. *With Lead.* Marine acid, whether in its concentrated or diluted state, has little effect upon lead, unless assisted by heat. If spirit of salt is poured on filings of lead, and the heat is increased so as to make the liquor boil and distil, a part of the acid will be retained by the metal, which will be corroded into a saline mass; and this, by a repetition of the process, may be dissolved into a limpid liquor. If lead is dissolved in aquafortis, and spirit of sea-salt, or sea-salt itself, added, a precipitation of the metal ensues; but if some aqua-regia is added, the precipitate is redissolved.

812 Plumbum corneum.

The combination of lead with marine acid, has, when melted, some degree of transparency and flexibility like horn; whence, and from its resemblance to luna cornea, it is called *plumbum corneum.* This substance is used in preparing phosphorus, according to Mr Margraaf's method.

813 Quicksilver.

XI. *With Quicksilver.* Marine acid in its limpid state, whether concentrated or diluted, has no effect upon quicksilver, even when assisted by a boiling heat; but if mercury is dissolved in the vitriolic or nitrous acids, and sea-salt, or its spirit, is added to the solution, it immediately precipitates the quicksilver in the same manner as it does silver or lead.

814 Corrosive sublimate.

If concentrated marine acid, in the form of vapour, and strongly heated, meets with mercury in the same state, a very intimate union takes place; and the produce is a most violent corrosive and poisonous salt, called *corrosive sublimate mercury.* This salt is soluble, though sparingly, in water; but is far from being perfectly saturated with mercury; for it will readily unite with almost its own weight of fresh quicksilver, and sublime with it into a solid white mass (which, when levigated, assumes a yellowish colour) called *mercurius dulcis, aquila alba*, or *calomel.*

815 Different methods of making.

There have been many different ways of preparing corrosive mercury, recommended by different chemists. Neumann mentions no fewer than ten. 1. From mercury, common salt, nitre, and vitriol. 2. From mercury, common salt, and vitriol. 3. Mercury, common salt, and spirit of nitre. 4. Solution of mercury in aquafortis, and salt. 5. Solution of mercury in aquafortis, and spirit of salt, or the white precipitate. 6. Mercury, common salt, nitre, and oil of vitriol. 7. Edulcorated turbith mineral, and common salt. 8. Red precipitate, common salt, and oil of vitriol. 9. Edulcorated turbith mineral, and spirit of salt. 10. Mercury, sal ammoniac, and oil of vitriol.

From a view of these different methods, it is evident, that the intention of them all is to combine the marine acid with quicksilver; and as this combination can be effected without making use of the nitrous acid, the greatest chemists have imagined that this acid, which is by far the most expensive of the three, might be thrown out of the process altogether, and the sublimate be more conveniently made by directly combining marine acid and mercury in a process similar to the distillation of spirit of salt. This method was formerly recommended by Kunckel; then published in the memoirs of the Academy of Sciences for 1730; and has been adopted and recommended by Dr Lewis.

The process consists in dissolving mercury in the vitriolic acid, as directed for making turbith mineral. The white mass remaining on the exsiccation of this solution is to be triturated with an equal weight of dried salt, and the mixture is then to be sublimed in a sand-heat; gradually increasing the fire till nothing more arises.

816 Differences of quality.

Neumann observes, that there is a considerable difference in the quality of sublimates made by the different methods he mentions; particularly in those made with or without nitre. This we have also found to be the case; and that sublimate made without the nitrous acid is never so corrosive, or soluble in water, as that which is made with it: nor will it afterwards take up so large a quantity of crude mercury as it otherwise would, when it is to be formed into calomel. The above process, therefore, tho' very convenient and easy, is to be rejected; and some other in which the nitrous acid is used, substituted in its stead. The reason of these differences is, that the spirit of salt must by some means or other be dephlogisticated before it can unite in sufficient quantity with the metal, into the compound desired, which is accomplished by the addition of nitrous acid.

From Tachenius, Neumann gives us the following process, which he says was the method of making sublimate at London, Venice, and Amsterdam. Two hundred and eighty pounds of quicksilver, 400 pounds of calcined vitriol, 200 pounds of nitre, the same quantity of common salt, and 50 pounds of the caput mortuum remaining after a former sublimation, or (in want of it) of the caput mortuum of aquafortis, making, in all, 1130 pounds, are well ground, and mixed together; then set to sublime in proper glasses placed in warm ashes, the fire is increased by degrees, and continued for five days and nights. In the making such large quantities, he says, some precautions are necessary, and which those constantly employed herein are best acquainted with. The principal are, the due mixture of the ingredients, which in some places is performed in the same manner as that of the ingredients for gun-powder: that a head and receiver be adapted to the subliming glass, to save some spirit of nitre which will come over. (Here a bent tube of glass will answer the purpose, as already mentioned). The fire must not be raised too hastily. When the sublimate begins to form, the ashes must be removed a little from the sides of the glass, or the glass cautiously raised up a little from the ashes. (This last, we think, is highly imprudent.) Lastly, the laboratory must have a good chimney, capable of carrying off the noxious fumes. The above-mentioned quantities commonly yield 360 pounds of sublimate; the 280 pounds of quicksilver gaining 80 from the 200 pounds of sea-salt. The makers of sublimate

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limate in France, he says, employ, in one operation, only 20 pounds of mercury. This they dissolve in aquafortis, evaporate the solution to dryness, mix the dry matter with 20 pounds of decrepitated sea-salt and 60 of calcined vitriol, and then proceed to sublimation.

817 Observations on the different methods.

The above processes, particularly the last, are unexceptionable as to the production of a sublimate perfectly corrosive; but the operation, it is evident, must be attended with considerable difficulty, by reason of the large quantity of matter put into the glass at once. We must remember, that always on mixing a volatile salt with a quantity of fixed matter, the sublimation of it becomes more difficult than it would have been had no such matter been mixed with it. It is of considerable consequence, therefore, in all sublimations, to make the quantity of matter put into the glass as little as possible. It would seem more proper, instead of the calcined vitriol used in the processes last mentioned, to dissolve the mercury in the vitriolic acid, as directed in turbith mineral, and sublime the dry mass mixed with nitre and sea-salt.

818 Supposed adulteration with arsenic.

It has been said, that corrosive sublimate mercury was frequently adulterated with arsenic; and means have even been pointed out for detecting this supposed adulteration. These means are, to dissolve a little of the suspected salt in water, and add an alkaline lixivium to precipitate the mercury. If the precipitate was of a black colour, it was said to be a certain sign of arsenic. This, however, shows nothing at all, but that either the alkali contains some inflammable matter, which, joining with the precipitate, makes it appear black; or that the sublimate is not perfectly corrosive; for if a volatile alkali is poured on levigated *mercurius dulcis*, the place it touches is instantly turned black.

819 Mercurius dulcis.

Mercurius dulcis, or calomel, is prepared by mixing equal parts, or at least three of quicksilver with four of sublimate; after being thoroughly ground together in a glass or stone mortar, they are to be poured through a long funnel into a bolt-head, and then sublimed. The medicine has been thought to be improved by repeated sublimations, but this is found to be a mistake. Mr Beaumé has found that mercurius dulcis cannot be united with corrosive sublimate in the way of sublimation; the former, by reason of its superior volatility, always rises to the top of the vessel.

820 Zinc volatilized.

XII. *With Zinc.* This semimetal dissolves readily in the marine acid into a transparent colourless liquor. It is volatilized, as well as most other metallic substances by this combination, as appears from the following process delivered by Neumann.

"Equal parts of filings of zinc and powdered sal ammoniac being mixed together, and urged with a gradual fire in a retort; at first arose, in a very gentle heat, an excessively penetrating volatile spirit, so strong as to strike a man down who should inadvertently receive its vapour freely into the nose. This came over in subtile vapours, and was followed by a spirit of salt in dense white fumes. In an open fire, white flowers succeeded; and at length a reddish and a black butter. In the bottom of the retort was found a portion of the zinc in its metallic form, with a little ponderous and fixed butyraceous matter which liquefied in the air. The lump was far more brittle than zinc ordinarily is; of a reddish colour on the outside, and blackish within. The bottom of the retort was variegated with yellow and red colours, and looked extremely beautiful. The remaining zinc was mixed afresh with equal its weight of sal ammoniac, and the process repeated. A volatile alkaline spirit and marine acid were obtained as at first; and in the retort was found only a little black matter. When the zinc was taken at first in twice the quantity of the sal ammoniac, the part that preserved its metallic form proved less brittle than in the foregoing experiment, and the retort appeared variegated in the same manner. On endeavouring to rectify the buttter, the retort parted in two by the time that one half had distilled." The nature of this combination is unknown.

821 Butter of antimony.

XIII. *With Regulus of Antimony.* This semimetal cannot be united with the marine acid unless the latter is in its most concentrated state. The produce is an excessively caustic thick liquid, called *butter of antimony*. The process for obtainining this butter is similar to that for distilling the smoking spirit of Libavius. Either crude antimony, or its regulus, may be used: for the spirit of salt will attack the reguline part of this mineral without touching the sulphureous. Three parts of corrosive sublimate are to be mixed with one of crude antimony; the mixture to be digested in a retort set in a sand-heat; the marine acid in the sublimate will unite with the reguline part of the antimony. Upon increasing the fire, the regulus arises, dissolved in the concentrated acid, not into a liquid form, but that of a thick unctuous substance like butter, from whence it takes its name. This substance liquefies by heat, and requires the cautious application of a live coal to melt it down from the neck of the retort. By rectification, or exposure to the air, it becomes fluid like oil but still retains the name of butter. If water is added to butter of antimony, either when in a butyraceous form, or when become fluid by rectification, the antimony is precipitated in a white powder called *powder of algaroth*, and improperly *mercurius vitæ*. This powder is a violent and very unsafe emetic. The butter itself was formerly used as a caustic; but it was totally neglected in the present practice, until lately that it has been recommended as the most proper material for preparing emetic tartar. (See below.) Mr Dollfuss recommends the following method as the best for making butter of antimony; *viz.* two ounces and a quarter of the grey calx of antimony, eight ounces of common salt, and six of acid of vitriol. By distilling this mixture, ten ounces of the antimonial caustic were obtained; and in order to determine the quantity of metal contained in it, he mixed two ounces of the caustic with four ounces of water; but thus such a strong coagulum was formed, that he was not able to pour off any of the water even after standing 24 hours. The precipitate, when carefully dried, weighed 50 grains. The result was much the same when glass of antimony was used, only that the precipitate was much more considerable, half an ounce of the caustic then yielding 60 grains, though at another time only 50 grains were obtained. In the re-

siduum

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ſiduum of the former experiment he found 30 grains of an earthy ſubſtance, chiefly a combination of calcareous earth with mariatic acid.

When the mercurius vitæ precipitates, the union between the marine acid and regulus is totally diſſolved; ſo that the powder, by frequent waſhings, becomes perfectly free from every particle of acid, which unites with the water made uſe of, and is then called very improperly, *philoſophic ſpirit of vitriol*.

822 Sympathetic ink.

XIV. *With Regulus of Cobalt.* Pure ſpirit of ſalt diſſolves this ſemimetal into a reddiſh yellow liquor, which immediately becomes green from a very gentle warmth. On ſaturating the ſolution with urinous ſpirits, the precipitate appears at firſt white, but afterwards becomes blue, and at length yellow. If the nitrous acid is added to ſolutions of regulus of cobalt, they aſſume a deep emerald green when moderately heated, and on cooling become red as at firſt. Duly evaporated, they yield roſe-coloured cryſtals, which change their colour by heat in the ſame manner. This ſolution makes a curious ſympathetic ink, the invention of which is commonly aſcribed to M. Hellot, though he himſelf acknowledges that he received the firſt hint of it from a German chemiſt in 1736. Any thing wrote with this ſolution is inviſible when dry and cold; but aſſumes a fine green colour when warm, and will again diſappear on being cooled; but if the heat has been too violent, the writing ſtill appears. M. Hellot obſerves, that if nitre or borax be added to the nitrous ſolution, the characters wrote with it become roſe-coloured when heated, and if ſea-ſalt is afterwards paſſed over them, they become blue; that with alkali ſufficient to ſaturate the acid, they change purple and red with heat.—A blue ſympathetic ink may be made from cobalt in the following manner. Take of an earthy ore of cobalt, as free from iron as poſſible, one ounce. Bruiſe it, but not to too fine a powder. Then put it into a cylindrical glaſs, with 16 ounces of diſtilled vinegar, and ſet the mixture in hot ſand for the ſpace of ſix days, ſtirring it frequently; or elſe boil it directly till there remain but four ounces. Filter and evaporate it to one half. If your ſolution be of a roſe colour, you may be certain that your cobalt is of the right ſort. A red brown colour is a ſign of the ſolution containing iron; in which caſe the proceſs fails. To two ounces of the ſolution thus reduced, add two drachms of common ſalt.—Set the whole in a warm place to diſſolve, and the ink is made.

823 Oil of arſenic.

XV. *With Regulus of Arſenic.* This ſubſtance is ſoluble in all acids; but the nature of the compounds formed by ſuch an union is little known. If half a pound of regulus is diſtilled with one pound of corroſive ſublimate, a thin ſmoking liquor and a butyraceous ſubſtance will be obtained, as in making the ſmoking liquor of Libavius. By repeated rectifications, this butter may be almoſt all converted into ſpirit. If equal parts of the arſenic and ſublimate are uſed, a ponderous black oil comes over along with the ſpirit, which cannot be mixed with it. By rectification in a clean retort they will become clear, but ſtill will not incorporate. If they are now returned upon the red maſs remaining in the firſt retort, and again diſtilled, a much more ponderous oil than the former will be obtained.

824 Marine ether.

XVI. *With Inflammable Subſtances.* The acid of ſea-ſalt is very little diſpoſed to contract any union with the phlogiſton, while in a liquid ſtate; and much leſs ſo, even in its moſt concentrated ſtate, than either the vitriolic or nitrous. Mr Beaumé, however, has found, that a ſmall quantity of ether, ſimilar to that prepared with the vitriolic and nitrous acids, may be obtained by cauſing the fumes of the marine acid unite with thoſe of ſpirit of wine. Others, and particularly ſome German Chemiſts, attempted to make this liquor, by employing a marine acid previouſly combined with metallic ſubſtances, ſuch as butter of antimony. The ſmoking liquor of Libavius ſucceeds beſt. If equal parts of this liquor and highly rectified ſpirit of wine are diſtilled together, a conſiderable quantity of true ether is produced; but which, like the vitriolic and nitrous ether, muſt be rectified in order to its greater purity. The tin contained in the ſmoking liquor is ſeparated and precipitated in white powder. In this proceſs, the acid is probably more diſpoſed to unite with the ſpirit of wine, by having already begun to combine with the inflammable principle of the metal.—For marine ether, Mr Dollfuſs recommends to put into a retort four ounces of digeſtive ſalt previouſly well dried and powdered, and two ounces of manganeſe; pouring upon this a mixture of five ounces of ſpirit of wine and two of oil of vitriol; the firſt five ounces and a half of the diſtilled liquor being poured back on the reſiduum, and the whole afterwards drawn off by a gentle heat. The ſpirit of ſalt thus obtained had a very penetrating agreeable odour, ſomewhat like that of nitrous ether; and at firſt ſwam upon the top of water; but at length mixed with it on being agitated for a long time. Towards the end of the diſtillation a little oil was obtained, which did not mix with the water; and by the addition of four ounces more of ſpirit of wine, more of the dulcified acid was obtained. With regard to this kind of ether, however, Mr Weſtrumb denies that it can be made by any method hitherto known; and inſiſts, that all the liquids as yet produced under the name of marine ether are in reality dulcified ſpirit of ſalt, and not true ether, which will ſwim on the top of water.

825 Attraction for phlogiſton.

Dr Prieſtley has obſerved, that the pure marine acid, when reduced to an inviſible aerial ſtate, has a ſtrong affinity with phlogiſton; ſo that it decompoſes many ſubſtances that contain it, and forms with them an air permanently inflammable. By giving it more time, it will extract phlogiſton from dry wood, cruſts of bread not burnt, dry fleſh; and, what is ſtill more extraordinary, from flints. From what has been above related, it appears that the dephlogiſticated ſpirit of ſalt has a very ſtrong attraction for phlogiſton.

Eſſential oil of mint abſorbed the marine acid air pretty faſt, and preſently became of a deep brown colour. When taken out of this air, it was of the conſiſtence of treacle, and ſunk in water, ſmelling differently from what it did before; but ſtill the ſmell of the mint was predominant. Oil of turpentine was alſo much thickened; and became of a deep brown colour, by being ſaturated with acid air. Ether abſorbed the air very faſt; and became firſt of a turbid white, and then of a yellow and brown colour. In one night a conſiderable quantity of ſtrongly inflammable air was produced.

Having once ſaturated a quantity of ether with acid air,

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air, he admitted bubbles of common air to it, through the quickſilver by which it was confined, and obſerved that white fumes were made in it, at the entrance of every bubble, for a conſiderable time. Having at another time, ſaturated a ſmall quantity of ether with this kind of air, and the phial which contained it happenning to be overturned, the whole room was inſtantly filled with a white cloud, which had very much the ſmell of ether, but peculiarly offenſive. Opening the door and window of the room, this light cloud filled a long paſſage and another room. The ether, in the mean time, was ſeemingly all vaniſhed: but, ſometime after, the ſurface of the quickſilver in which the experiment had been made was covered with a very acid liquor, ariſing probably from the moiſture in the atmoſphere, attracted from the acid vapour with which the ether had been impregnated. This ſeems to ſhow, that however much diſpoſed the marine acid may be to unite with phlogiſtic matters when in its aerial ſtate, the attraction it has for them is but very ſlight, and ſtill inferior to what it has for water.

Camphor was preſently reduced into a fluid ſtate by imbibing this acid air; but there ſeemed to be ſomething of a whitiſh ſediment in it. After continuing two days in this ſituation, water was admitted to it, upon which the camphor immediately reſumed its former ſolid ſtate; and to appearance was the ſame ſubſtance that it had been before.

Strong concentrated oil of vitriol, being put to marine acid air, was not at all affected by it in a day and a night. In order to try whether it would not have more power in a condenſed ſtate, it was compreſſed with an additional atmoſphere; but, on taking off this, the air expanded again, and was not in the leaſt diminiſhed. A quantity of ſtrong ſpirit of nitre was alſo put to it without any ſenſible effect. From theſe laſt experiments it appears, that the marine acid is not able to diſloge the other acids from their union with water.

ad 825 New acid diſcovered by Mr Homberg.

Beſides the acids already mentioned, Mr Homberg deſcribes an artificial one generated by mixing two ounces and a half of luna cornea, with an ounce and a half of tin calcined alone and without addition, by means of fire. The mixture is to be expoſed to a naked fire in a coated retort, of which two-thirds ought to be left empty; when a browniſh matter, an ounce and a half in weight, will adhere to the neck of the retort. This matter is tin combined with the marine acid, and the reſiduum is ſilver deprived of the ſame acid, which may therefore now be melted together without any loſs. The ſublimate, well powdered and dried, is to be equally divided into two phials, and ſublimed; by repeating which operation two or three times, a volatile ſalt, of an acid nature, very white and tranſparent, is obtained. The reſiduum of theſe ſublimations is always calx of tin.

§ 4. *Of the* Fluor *Acid.*

826 Firſt diſcovered by Mr Margraaf.

This acid was diſcovered ſometime ago by Mr Margraaf, and more fully inveſtigated by Mr Scheele. The experiments by which it was originally produced, and its properties aſcertained, are as follows:

827 How prepared.

I. Two ounces of concentrated vitriolic acid were poured upon an equal quantity of fluor, which had been previouſly pounded in a glaſs mortar, and then put into a retort, to which a receiver was adapted, and the juncture cloſed with grey blotting paper. On the application of heat, the maſs began to effervеſce and ſwell, inviſible vapours penetrated every where through the joining of the veſſels, and towards the end of the proceſs white vapours aroſe, which covered all the internal parts of the receiver with a white powder.—The maſs remaining in the retort was as hard as a ſtone, and could not be taken out without breaking the veſſel. The lute was quite corroded and friable.

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II. The proceſs was repeated exactly in the ſame manner, excepting only that a quantity of diſtilled water was put into the receiver. A white ſpot ſoon began to form on the ſurface of the water, juſt in the centre, and immediately under the mouth of the retort. This ſpot continually increaſed, till at laſt it covered the whole ſurface of the water, forming a pretty thick cruſt, which prevented the communication of the water with new vapours that came over. On gently agitating the receiver, the cruſt broke, and fell to the bottom; ſoon after which a new cruſt like the former was produced. At laſt the receiver, and ſoon after the retort alſo, became white in the inſide. The veſſels, when cooled, were found much corroded internally. In the receiver was an acid liquor mixed with much white matter, ſeparable by filtration.

828 Forms a white earthy cruſt with water

III. This white matter when edulcorated and dried, ſhowed itſelf to be ſiliceous earth by the following properties. 1. It was rare, friable, and white. 2. It was not ſenſibly ſoluble in acids. 3. It did not make a tough paſte with water, but was looſe and incoherent after being dried. 4. It diſſolved by boiling in lixivium tartari, and the ſolution in cooling aſſumed a gelatinous conſiſtence. 5. In its pure ſtate it ſuffered no change in the ſtrongeſt heat; but when mixed with alkali, it boiled, frothed up, and formed a glaſs in a melting heat. 6. It diſſolved in borax without ſwelling.

829 Which has the properties of ſiliceous earth.

IV. To determine whether this earth was formed during the proceſs, he poured vitriolic acid upon powdered fluor contained in a cylinder of braſs which was cloſed exactly with a cover, after having ſuſpended over the mixture an iron nail and a bit of charcoal. On opening the veſſel two hours afterwards, he found the nail and charcoal unchanged; but on moiſtening them, he found both covered with a white powder in a ſhort time. This powder had all the properties of ſiliceous earth; and as in the experiment he had made no uſe of glaſs veſſels, he concluded that it did not proceed from the glaſs veſſels as might have been ſuſpected from their being ſo much corroded, but was generated in ſome other way.

830 Scheele's experiment to determine the origin of this earth.

V. Having recompoſed fluor by ſaturating the acid with calcareous earth, he treated the compound in the ſame manner as the natural fluor, with a ſimilar reſult; and repeating the experiment five times over, he conſtantly found the ſiliceous earth and acid diminiſh conſiderably, ſo that at laſt ſcarce any mark of acidity was left. Thence he concluded, that all the fluor acid united itſelf by degrees with the vapours of the water, and thus formed the ſiliceous earth. "It may be objected (ſays Mr Scheele), that the fluor acid is perhaps already united by nature with a fine ſiliceous powder,

831 Artificial fluor yields a ſimilar reſult.

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der, which it volatilizes, and carries over in diſtillation, but leaves it as ſoon as it finds water to unite with, juſt as muriatic acid parts with the regulus of antimony, when butter of antimony is dropped into water. But if this was the caſe, the fluor acid would leave the whole quantity of ſiliceous earth thus combined with it in the firſt diſtillation, and therefore ſhow no mark of its preſence in the following proceſſes. When I put ſpirit of wine into the receiver inſtead of water no ſiliceous earth was produced; but the alcohol became ſour. When I put an unctuous oil into the receiver, all the fluor acid penetrated through the crevices of the lute, and neither united with the oil, nor produced a ſiliceous earth. This happened alſo when acid of vitriol was put into the receiver. If therefore the ſiliceous earth was not a product of each diſtillation, but, being previouſly contained in the acid, was only depoſited from it in conſequence of the union of the acid with a third ſubſtance, I think the ſiliceous earth ought equally to appear when alcohol was put into the receiver, with which it unites, as well as with water; but as this does not happen, I conclude that not all the ſiliceous earth, which is depoſited upon the ſurface of water during the diſtillation of the fluor acid, was previouſly diſſoved in this acid."

832 Mr Scheele's concluſion that the earth proceeds from an union of the acid with water.

833 Conteſted by Meſſrs Boullanger Monnet, &c.

This opinion of Mr Scheele did not meet with general approbation. M. Boullanger endeavoured to ſhow, that the fluor acid is no other than the muriatic intimately combined with ſome earthy ſubſtance; and Mr Monnet maintained that it is the ſame with that of vitriol volatilized by ſome extraordinary connection with the fluor; which opinion was alſo maintained by Doctor Prieſtley. Mr Scheele conteſted theſe opinions, but found much greater difficulty in ſupporting his own opinions than in overthrowing thoſe of his adverſaries. Boullanger inſiſted that fluor acid precipitates the ſolutions of ſilver and quickſilver, producing luna cornea with the former, and mercurius dulcis with the latter. Mr Scheele owns that fluor acid precipitates both theſe metals, but the precipitate obtained is in very ſmall quantity, and the little that is produced ariſes only from a ſmall quantity of ſea-ſalt with which the fluor, as well as all other calcareous ſubſtances, is generally mixed. The greateſt part of the acid, therefore, will not precipitate the ſolutions of theſe metals, which it ought to do upon Mr Boulanger's hypotheſis. Mr Scheele then proceeds to ſhow a method of ſeparating this ſmall quantity of marine acid from that of fluor. A ſolution of ſilver made with nitrous acid is to be precipitated with alkali of tartar, and as much acid of fluor poured upon the edulcorated powder as is ſufficient to give an exceſs of acid; after which the ſolution is to be filtered. This ſolution of ſilver in fluor acid is then to be dropped into that acid we deſire to purify, till no more precipitation enſues; after which the acid is filtered through grey paper, and diſtilled to dryneſs in a glaſs retort. The aqueous part comes over firſt, but is ſoon followed by fluor acid, which covers the inſide of both the veſſels, together with the ſurface of the water in the receiver, with a thick ſiliceous cruſt. The acid thus rectified, does not precipitate ſolution of ſilver in the leaſt, or otherwiſe ſhow the ſmalleſt ſign of muriatic acid.

834 Their opinions ſhown to be erroneous by Mr Scheele.

835 Fluor acid proved to be different from that of ſea-ſalt,

836 And from that of vitriol.

That the fluor acid is different from that of vitriol Mr Scheele proved by the following experiment. Upon one ounce of pure levigated fluor with alkohol, he poured three ounces of concentrated oil of vitriol, and diſtilled the mixture in a ſand-bath, having previouſly put 12 ounces of diſtilled water into the receiver. He then took other three ounces of the ſame acid diluted with 24 ounces of water, to which he afterwards added lixivium tartari previouſly weighed, till he attained the exact point of ſaturation. After the diſtillation he weighed the remaining lixivium; having kept up ſuch a degree of heat for eight hours as was not ſufficient to raiſe the vitriolic acid. On breaking the retort, and reducing the maſs to powder he boiled it in a glaſs veſſel with 24 ounces of water for ſome minutes; after which he added juſt as much lixivium tartari as he had found before to be requiſite for the ſaturation of three ounces of the vitriolic acid, and continued the boiling for a few minutes longer. On examining the ſolution, it was found to contain a vitriolated tartar perfectly neutralized, neither acid nor alkali prevailing in any degree; which ſhowed that no vitriolic had paſſed into the receiver. The ſaline matter being then extracted with hot water, the remaining earth was found to weigh 9¼ drachms. Two drachms of this diſſolved in muriatic acid, excepting only a ſmall quantity of matter which ſeemed to be fluor undecompoſed, and which on being dried weighed only nine grains. Into one part of this ſolution he poured ſome acid of ſugar, and into another vitriolic acid. The former produced ſaccharated lime, and the latter gypſum. A third part was evaporated to dryneſs, and left a deliqueſcent ſalt; and the remaining part of the earth burned in a crucible, produced a real quicklime.

837 Quicklime the baſis of fluor.

Thus it appeared that the real baſis of fluor is quicklime, and likewiſe that the fluor acid is different from that of vitriol, as appears farther from the following conſiderations: 1. Pure fluor acid does not precipitate terra ponderoſa, nor ſolution of lead in nitrous acid. 2. The ſame acid, when ſaturated with alkali of tartar, evaporated to dryneſs, and afterwards melted with powdered charcoal, does not produce any hepar ſulphuris.

838 Miſtake of Mr Monnet on this ſubject.

Mr Monnet, in order to ſupport his hypotheſis, denies that fluor contains any calcareous earth. In proof of which he adduces the following experiment: Equal quantities of alkali and fluor were melted together, with little or no change on the mineral; for, after having taken away by lixiviation the alkali employed, he diſſolved the fluor remaining on the filter in nitrous acid, adding vitriolic acid to the ſolution; and becauſe he obtained no precipitate, concluded at once, that fluor contains no calcareous earth. Mr Scheele on the contrary affirms, that all ſolutions of fluor yield a precipitate of gypſum whenever vitriolic acid is added to them. He explains Mr Monnet's failure, by ſuppoſing that he had diluted his ſolution with too great a quantity of water.

839 Wiegleb's experiments on the origin of the ſiliceous earth

Mr Wiegleb, diſſatisfied with the hypotheſis of Scheele, as well as others, concerning the fluor acid, began a new ſet of experiments on the mineral. Having firſt accurately repeated thoſe made by Mr Scheele, he proceeded to inquire into the origin of the ſiliceous earth, in the following manner: Having firſt weighed the retort deſtined for the experiment in an

Fluor acid and its combinations.

an accurate manner, and found that its weight was two ounces and five drachms, he put into it two ounces of calcined fluor in powder, adding, by means of a glafs tube, $2\frac{1}{4}$ ounces of oil of vitriol. The retort was then placed on the furnace; and a receiver, which when empty weighed two ounces, two drachms, and 30 grains, and now contained two ounces of diftilled water, was luted to it. The diftillation was conducted with all poffible care, and at laft pufhed till the retort grew red hot; but it was found impoffible to prevent a few vapours from penetrating through the lute. Next day the retort, feparated from the receiver, was found to weigh, together with its contents, five ounces, five drachms, and 30 grains; and confequently had loft in weight one ounce, three drachms, and 30 grains, The receiver, which, with the water, had originally weighed four ounces, two drachms, and 30 grains, now weighed five ounces and three drachms, and had therefore gained one ounce and 30 grains. This gain, compared with the lofs of the retort, fhows that the retort loft more by three drachms than the receiver gained; fo that thefe muft have undoubtedly paffed through the luting in form of vapour.

To determine the point in queftion, the empty veffels, with what had been put into them, were accurately weighed; when the weights and lofs upon the whole were found to be as follows.

	oz.	dr.	gr.
The empty retort - -	2	5	0
Calcined fluor - - -	2	0	0
Oil of vitriol - -	2	4	0
Total weight before diftillation	7	1	0
After it -	5	5	30
Lofs of retort - -	1	3	30
The empty receiver weighed -	2	2	30
The water put into it - -	2	0	0
Total weight before diftillation	4	2	30
Total weight after diftillation -	5	3	0
Gain of receiver -	1	0	30

Deducting this grain of weight in the receiver from the lofs of weight in the retort, we find, that three drachms were wanting on the whole, which muft undoubtedly, as already obferved, have been diffipated in vapour. The retort being now broken, and the dry earth both in its neck and arch feparated as accurately as poffible, it was found to weigh three drachms; the refiduum in the retort weighed three ounces, two drachms, and 40 grains. Now, as the mafs in the retort had originally weighed four ounces and four drachms, it appeared, by deducting the refiduum, to have fuffered, on the whole, a lofs of one ounce, one drachm, and 20 grains. To determine the lofs more accurately, the following calculations were made:

	oz.	dr.	gr.
The white earth feparated from the neck and arch of the retort -	0	3	0
Gain of the receiver - -	1	0	30
Loft in vapour - - - -	0	3	0
Total	1	6	3

Here Mr Wiegleb was furprifed to find, that the matter which came from the retort amounted to more by five drachms ten grains than the mafs in the retort had loft of its original weight; to illuftrate which it was neceffary to weigh the retort and receiver by themfelves. The pieces of the retort now weighed only one ounce feven drachms and 50 grains; whereas, before the procefs, the weight of the retort was two ounces five drachms. It appeared, therefore, that it had loft five drachms ten grains, the very quantity which had been gained by the receiver. This laft had loft nothing of its original weight.

The fluid in the receiver was next diluted with four ounces of diftilled water, and the whole poured out on a filter, in order to feparate the earthy matter with which it was mixed, and frefh water poured upon it to take out all the acid: after which the earth was dried, and found to weigh 57 grains. The clear liquor was then diluted with more diftilled water, and afterwards precipitated with fpirit of fal ammoniac prepared with fixed alkali. A brifk effervefcence took place before any precipitate began to fall, but ceafed foon after the precipitation took place. The whole mixture become gelatinous; and the precipitate, when dry, weighed two drachms. The whole quantity of earth, therefore, obtained in this procefs amounted to five drachms 47 grains, which is forty-feven grains more than the retort had loft in weight. This excefs is, by our author, attributed to part of the acid ftill adhering to it, and to the acceffion of fome moifture from the air; to determine which he heated each of the parcels of earth red hot feparately, and thus reduced them to four drachms 52 grains, which is lefs by 18 grains than the lofs of the retort, and which, he is of opinion, muft have efcaped in the three drachms of vapour.

840

The earthy cruft proceeds from the folution of the glafs diftilling veffels.

From this experiment Mr Wiegleb concludes, that the earth produced in the diftillation of fluor proceeds neither from the fpar nor from a combination of the acid with water, but from the folution of the glafs by the fparry acid. To his opinion alfo Dr Crell accedes. "In diftilling fluor (fays he) with oil of vitriol, I have found the retort as well as the receiver very much corroded. I poured the acid obtained by the procefs into a phial furnifhed with a glafs ftopper, and obferved after fome time confiderable depofition. I then poured the liquor into another phial like the former; and that it might neither on the one hand attack the glafs, nor on the other compofe filiceous earth with the particles of water, according to Mr Scheele's hypothefis, I added highly rectified fpirit of wine. I faw, however, after fome time, another confiderable depofition. This feemed alfo to proceed from the glafs that had been before diffolved, which the acid let fall in confequence of the gradual combination with the fpirit of wine; otherwife we muft fuppofe, what to me appears incredible, that the acid decompofes the fpirit, attracts the water, and forms the earth."

841

Mr Meyer's examination of the fluor acid.

This fingular acid has been ftill further examined by Mr Meyer. He informs us, that, among Mr Scheele's experiments, he was particularly ftruck by one in which no earthy cruft was obtained, after putting fpirit of wine into the receiver. Mr Meyer repeated this experiment, hoping, that when but little fpirit was put into the receiver, he might be able to procure a new kind of ether. An ounce of finely powdered fluor, which had been previoufly heated red hot, was put into a glafs

glaſs retort, to which was fitted a receiver containing three ounces of highly rectified French brandy. The diſtillation was continued for three hours with a gentle heat: when the acid, having made its way through the bottom, put and end to the proceſs. No cruſt could be perceived on the ſurface of the ſpirit: but in the place where it had been in contact with the receiver there was a thin ring of tranſparent jelly. The ſame mixture of oil of vitriol and fluor was therefore again put into a retort of very ſtrong glaſs, and the ſame ſpirit put into the receiver. The diſtillation was conducted two hours with a gentle and afterwards with a ſtronger, heat. When it was half over, the ſpirit began to change into a thin jelly; and at the end of the proceſs ſome firmer pieces were found at the bottom. Theſe were waſhed with ſpirit of wine; and in order to obtain the ſpirit together with the acid in a pure ſtate, it was put into a large retort, and again ſubjected to diſtillation. As the retort grew warm, the opal-coloured ſpirit became clear and ſwelled, what remained becoming again gelatinous; a good deal of earth remained behind, but did not adhere firmly to the retort, which was ſmooth in the inſide, though full of ſhallow excoriations. It was alſo evident, that the glaſs was actually corroded, and that the earthy matter is not a mere cruſt adhering to the inſide. The jelly being thoroughly edulcorated, as well as the earth that remained in the retort after the rectification, and that which was diſſolved in the water precipitated by ſpirit of ſal ammoniac, the whole quantity amounted to two drachms. That which had ſeparated ſpontaneouſly was ſemitranſparent. "As this earth (ſays he) ſhowed the properties of ſiliceous earth, and the glaſs, which was ſo much corroded, conſiſts in great meaſure of it, the greateſt part of it might come from the glaſs,

842 How to procure the acid free from ſiliceous earth,

and the reſt of it perhaps be a conſtituent part of the fluor itſelf. In order to aſcertain this it was neceſſary to obtain the fluor acid quite free from ſiliceous earth. I therefore expoſed the ley, which I had procured by the precipitation of the earth with ſal ammoniac, to a gentle evaporation in a ſlightly covered glaſs veſſel. The product was one drachm 56 grains of an ammoniacal ſalt; the glaſs did not appear to have been attacked. Half a drachm of this ſalt was ſublimed in a ſmall retort, which, towards the end of the operation, was laid on the bare fire. No cruſt appeared on the ſurface of the water in the receiver. At the bottom of the retort lay a little flocculent earth of a light grey colour, above which the internal ſurface was covered with a white pellicle that reflected various colours; and in the neck there was a ſublimate. The thin pellicle eaſily ſeparated in many places from the glaſs, which was ſmooth beneath, though not without ſome ſmall furrows. I poured water both upon the ammoniacal ſalt and cruſt; in conſequence of which it acquired a very ſour taſte, and coloured the tincture of turnſole red. The white cruſt that was left behind undiſſolved weighed five grains, and melted into a green glaſs without addition. This was nothing but the glaſs that had been corroded by the fluor acid; but as this acid can be ſet looſe only by ſtrong heat, it had done no more than corrode the glaſs, without paſſing over along with it in the form of vapour, and then depoſing it again on the water. For, upon pouring two drachms of oil of vitriol upon half a drachm of this ammoniacal ſalt a little moiſtened, and placed in a glaſs retort, a great foam aroſe, and the thick vapours that aſcended covered the water in the receiver with a white cruſt. A ſcruple of the ſalt on ſolution, left behind a grain of earth, which, as I conjecture, it had taken up during the evaporation in the glaſs veſſel."

To prevent this, our author diſtilled half an ounce of fluor with an ounce of oil of vitriol for five hours. The cruſts were ſeparated from the water; they weighed, after being well waſhed and dried, eleven grains; they were white and very flocculent; thirty-two grains of ſiliceous earth were precipitated from the filtered water: the ley was then evaporated in a leaden veſſel 843

843 Experiments made with an iron diſtilling veſſel.

and yielded 80 grains of ſalt. As glaſs veſſels were no longer to be truſted, a piece of a gun-barrel furniſhed with a cover, and terminated by a bent tube, intended to ſerve inſtead of the neck of a retort, was afterwards uſed; and with this apparatus the following experiments were made:

1. Half a drachm of the newly prepared ſal-ammoniac was diſtilled for two hours with two drachms of oil of vitriol, into a glaſs receiver containing an ounce of water. No veſtige of a cruſt could be perceived on the water, but ſome earth was perceived in the receiver, where the vapours having aſcended through the tube, came into contact with the wet glaſs; and here the ſurface was become ſenſibly rough. On the addition of volatile alkali, a few flocculi of ſiliceous earth, a mounting only to one-fourth of a grain, were thrown down out of the water.

2. A drachm of vitriol was added to a drachm and an half of the ſalt; but a leaden receiver was now uſed, containing an ounce of water as before. The water acquired an unpleaſant ſmell, but ſhowed no ſigns of a cruſt. On the addition of ſpirit of ſal ammoniac, a little grey earth weighing half a grain fell to the bottom.

844 No cruſt formed by mixing ſand, with a ſalt containing fluor acid.

3. A ſcruple of this ſalt, mixed with an equal quantity of white ſand in fine powder, and diſtilled with a drachm and an half of oil of vitriol, into an ounce of water in the leaden receiver, ſhowed no ſign of a cruſt. The water had a putrid ſmell, and left on the filter two grains and an half of grey earth, which ran under the blow-pipe into a grain of lead. Volatile alkali precipitated five grains of grey earth, which melted on the addition of a little ſalt of tartar into a black globule, though the blow-pipe alone made no change in it.

845 But a great one by uſing powdered glaſs.

4. To 13 grains of the ſame ammoniacal ſalt a drachm of oil of vitriol and two ſcruples of green glaſs, broken into ſmall pieces, were added. The iron tube had ſcarce become warm, when a great cruſt of ſiliceous earth was perceived on the ſurface of the water, and the ſame appearance on the moiſt ſides of the veſſel. It did not, however, ſeem to increaſe during the remainder of the diſtillation. A grain and a quarter of earthy matter remained on the filter, conſiſting partly of white films, which ran under the blow-pipe into a greeniſh glaſs.

5. To aſcertain this matter ſtill more clearly, a different ſpecies of mineral fluor was uſed, which being diſtilled with a double quantity of oil of vitriol, and with a drachm of water in the receiver, yielded a thin pellicle of the appearance of lead, but no ſiliceous cruſt. Volatile alkali threw down $2\frac{1}{4}$ grains of grey earth.

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earth.—A drachm mixed with the ſame quantity of pulverized ſand afforded a pellicle of lead interſperſed with a few particles of white cruſt, which ran into glaſs under the blow-pipe. Volatile alkali precipitated eight grains.—A drachm, mixed with an equal quantity of green glaſs reduced to powder, ſwelled a good deal, and yielded a thick ſiliceous cruſt.

6. To a drachm of green fluor that had been heated and powdered were added two drachms of oil of vitriol, ſtill employing the iron tube. A piece of wet charcoal was alſo ſuſpended in the inſide, a cover fixed on the tube, and the latter was heated for about 15 minutes in a ſand-bath. Obſerving now that the charcoal was dry, and had no earth upon it, a ſcruple of ſand in fine powder was added, the charcoal was wetted and replaced, but nothing appeared. Some bits of green glaſs were then thrown into the mixture which inſtantly foamed up and ran over. The charcoal was not replaced in the tube, nor was it any longer neceſſary, as it gained a covering of white powder by being held a very few moments over the orifice.

846
An experiment of Mr Scheele's explained.

Mr Scheele, in one of his experiments, obſerves, that he obſerved the white powder on a piece of charcoal that had been moiſtened and ſuſpended over fluor to which vitriolic acid was added. As this experiment was made in metallic veſſels, Mr Meyer conjectures, that the mortar uſed for reducing the fluor to powder was of ſoft glaſs, and that the phenomenon was occaſioned by the abraſion of ſome particles of glaſs.

847
Of the quantity of ſiliceous earth carried along with fluor acid.

7. To determine whether the acid can carry up much more of the ſiliceous earth than is ſufficient to ſaturate it, an ounce and an half of pure oil of vitriol was added in a retort of glaſs, and three ounces of water put into the receiver. The retort was corroded through in an hour's time, and the cruſt on the water weighed ten grains The liquid being then filtered and divided into two equal parts, one was precipitated with cauſtic volatile, and the other with mild fixed vegetable alkali. The former yielded 25 grains of ſiliceous earth, and the latter 68 grains of a precipitate, which flowed under the blow-pipe, ran into the pores of charcoal, and gave out ſtrong vapours of fluor acid. The reaſon of this difference ſhall be explained when we come to treat of ſiliceous earth.

848
Violent action of fluor acid upon glaſs.

8. To a mixture of half an ounce of fluor and the ſame quantity of glaſs, in powder, 12 drachms of oil of vitriol were put in a ſmall retort, half filled with the mixture. The ingredients acted upon each other ſo violently that they roſe up into the neck of the retort; and the operation being intermitted on account of the noxious vapour they emitted, the retort was found next day covered with faſciculated cryſtals like hoarfroſt.—The experiment being repeated in a more capacious retort, and the mixture thoroughly blended by agitation, it became a thick maſs, and ſwelled like dough in fermentation: the bottom of the retort grew very hot, and the ſiliceous cruſt appeared on three ounces of water in the receiver. The diſtillation being continued for three hours, 16 grains of ſiliceous earth were found on the ſurface, and the precipitate by volatile alkali weighed 56 grains; the retort was much leſs corroded than uſual.

9. Thirty grains of this precipitate, diſtilled in a glaſs retort with a drachm and an half of oil of vitriol, produced no ſiliceous earth on the water in the receiver, or that with which the earth was edulcorated. The ley of fluorated volatile alkali was mixed with a ſolution of chalk in nitrous acid till no more precipitation took place. The mixture was paſſed through nitrous acid, and the precipitate edulcorated. It weighed, when dry, two drachms and 36 grains.

10. Two drachms of oil of vitriol being added to a drachm of this precipitate contained in a glaſs retort, the precipitate was attacked in the cold, but no cruſt appeared; the heat, however, was ſcarce applied, when the whole ſurface of the water was covered, and the ſame phenomena exhibited which are produced by the natural fluor.

849
Farther proofs that the earthy cruſts proceeds from the glaſs veſſels.

11. Mr Scheele having obſerved that a mixture of fluor as tranſparent as mountain cryſtal, and oil of vitriol in a metallic cylinder, produced no appearance of ſiliceous earth, on a wet ſponge ſuſpended on the inſide, at Mr Meyer's requeſt he made a new experiment by adding oil of vitriol to portions of fluor of this tranſparent kind placed in two tin cylinders; ſome ſiliceous earth was put into one, and a wet ſponge ſuſpended in both. The next morning the ſponge that was ſuſpended over the cylinder which held the ſiliceous earth, was covered with the white powder, but no appearance of it was ſeen on the other. The experiment was repeated by Mr Meyer with the ſame reſult, but the white cruſt did not appear till after a night's ſtanding.

12. A drachm of fluor, mixed with two of oil of vitriol, afforded, after a diſtillation of two hours, a thin film of lead on the ſurface of the water in the receiver, but no ſiliceous earth. The ſame mixture was afterwards diſtilled with the uſe only of a glaſs receiver inſtead of a lead one. In the beginning of the diſtillation a ſmall ſpot appeared under the neck of the retort, and the neck itſelf was covered with white powder, but it ſoon diſappeared; and though the empty part of the receiver was corroded, yet no more than half a grain of earth was procured.

Theſe experiments ſo clearly point out the origin of the ſiliceous cruſt on the ſurface of the fluor acid, that its exiſtence as a diſtinct acid is now univerſally allowed, even by thoſe who formerly contended for its being only the vitriolic or ſome other acid diſguiſed.—

850
Mr Wenzel's experiments in a leaden retort.

Experiments of a ſimilar kind were made by Mr Wenzel, who performed his diſtillation in a leaden retort, furniſhed with a glaſs receiver. The water was covered with a variegated cruſt, and yielded a gelatinous precipitate with fixed alkali. On examining the receiver, he found its internal ſurface corroded, ſo that it appeared as if it had been rubbed with coarſe ſand. By ſubſtituting a leaden receiver, however, inſtead of a glaſs one, he obtained the acid entirely free from ſiliceous matter, and containing only a ſmall quantity of iron and aluminous earth.

2d 850
Fluor acid procurable by nitrous, muriatic, and phoſphoric acid.

The fluor acid may alſo be procured by the nitrous, muriatic, and phoſphoric acids.—Mr Scheele diſtilled one part of the mineral with two of concentrated nitrous acid. One part went over into the receiver along with the fluor acid, and a thick cruſt was formed on the water of the receiver. The maſs remaining in the retort was calcareous earth ſaturated with nitrous acid.

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With an equal quantity of marine acid, that of fluor passed over into the receiver with a large quantity of the muriatic; the internal surface of the receiver, as well as of the water contained in it, being covered with a white crust. The residuum was fixed sal ammoniac.

Phosphoric acid digested with powdered fluor, dissolved a good deal of it; and on distilling this solution, the fluor acid went over together with the watery particles of the mixture; the remaining mass in the retort had the properties of the ashes of bones.

3d 850 Appearance and properties of fluor acid.

The fluor acid procured in any of these ways is not distinguishable by the smell from that of sea-salt: in some cases it acts as muriatic acid, in others like that of tartar; but in most cases it shows properties peculiar to itself.

4th 850 Combined with fixed alkali.

With fixed alkali the fluor acid forms a gelatinous and almost insipid matter, which refuses to crystallize. By evaporation a saline mass was obtained, which was in weight only the sixth part of the fixed alkali dissolved; did not change the colour of syrup of violets, but precipitated lime water, and likewise the solutions of gypsum and Epsom salt. With mineral alkali the same phenomena were produced as with the vegetable.

851 With volatile alkali.

Volatile alkali with fluor acid formed likewise a jelly, which when separated from the liquor appeared to be siliceous earth. The clear liquid tasted like vitriolic ammoniac, and shot into very small crystals, which by sublimation yielded first a volatile alkali, and then a kind of acid sal ammoniac. By distillation with chalk and water, all the volatile alkali quickly came over. Lime water instantly threw down a regenerated fluor, which was the case also with solutions of lime in the nitrous and muriatic acids.—Solution of silver let fall a powder, which, before the blow-pipe, resumed its metallic form, the acid being dissipated, and forming a white spot on the charcoal round the reduced silver. Solution of quicksilver in nitrous acid was precipitated, and the powder was entirely volatile in the fire; but a solution of corrosive sublimate remained unchanged. Lead was totally precipitated from nitrous acid; and a solution of Epsom salt was rendered turbid. Oil of vitriol produced a fluor acid by distillation, which formed at the same time a thick crust on the water of the receiver. The regenerated fluor procured either by means of lime water or solutions of the earth in acids, was decomposed by fixed, but not by volatile alkali.

852 With earths.

With lime, magnesia, and earth of alum, this acid became gelatinous. Part of the two last were dissolved.

853 With metal.

Gold was not touched by the fluor acid either alone or mixed with that of nitre. Silver, in its metallic state, underwent no change. Its calx, precipitated by an alkali, was partly dissolved; but the remainder formed an insoluble mass at the bottom Vitriolic acid expelled the fluor acid in its usual form. Quicksilver was not dissolved, but its calx precipitated from the nitrous solution was partially so. The remaining insoluble part of the calx united with the acid, and formed a white powder, from which the fluor acid was expelled by the vitriolic. The same powder formed, by means of the blow-pipe, a yellowish glass; which, however, evaporated by degrees, leaving a small globule of fixed glass behind. Lead was not dissolved, but the acid formed a sweet solution with its calx; from whence the latter could be precipitated by the acids of vitriol, and sea-salt, as also by sal ammoniac. On digesting a quantity of acid with calx of lead, which had been previously digested in the same, a spontaneous precipitation took place. The precipitate melted easily before the blow-pipe, and ran into metal; but part of the glass remained fixed in the fire. Copper was partially dissolved, as appeared by the blue colour assumed by the liquid on the addition of volatile alkali. The calx of copper was easily soluble; and the liquor, though gelatinous, yielded blue crystals, partly of a cubic and partly of an oblong form, from which the acid could not be separated but by heat. Iron was violently attacked, and gave out inflammable vapours during the solution. The liquor refused to crystallize; but, by evaporation, congealed into an hard mass after the moisture was dissipated; and from this mass the fluor acid might be expelled as usual by oil of vitriol. The same effect was also produced by heat alone; the acid rising in vapours, and leaving a red ochre behind. Calx of iron was also dissolved, and the solution tasted like alum; but it could not be reduced to crystals. Tin, bismuth, and regulus of cobalt, were not attacked in their metallic state; but the calces of all of them were soluble. Regulus of antimony and powdered antimony were not sensibly acted upon. Zinc produced the same effects as iron, excepting that the solution seemed more inclined to crystallize.

854 Glass corroded by this acid, as well as the salt formed by its combination with volatile alkali.

The most remarkable property of this acid, however, is its readily dissolving glass and carrying it off in the form of vapour. This singular property belongs not only to the pure acid, but also to the ammoniacal salt formed by combining it with the volatile alkali. Mr Wiegleb informs us, that on evaporating to dryness, in a cup of Misnia porcelain, a solution of this kind of ammoniac, which by its smell showed an excess of volatile alkali, the glazing of the inside was entirely corroded, and the bottom left as rough as a file. During the evaporation the cup was covered with white paper, which when dry appeared full of small crystals of an acid taste, easily distinguishable by the naked eye. These, as well as the ammoniacal salt, powerfully attracted the moisture of the air.

855 It is very difficult to be kept.

This property of the fluor acid renders it extremely difficult to be kept. Mr Meyer informs us, that having kept some upwards of a year in a glass phial, it corroded the glass in many points surrounded with concentric circles, depositing a powder which adhered to the bottom. He is of opinion that golden vessels would be most proper for keeping this acid, as also for making experiments on the fluor itself. A phial covered in the inside with wax and oil has been recommended for the same purpose.

856 Golden vessels most proper for this purpose.

857 Dr Priestley's experiments on converting this acid into a kind of air.

This acid, as well as those of vitriol, nitre, and sea-salt, has been exhibited by Dr Priestley in an aerial form. Having put some pounded spar into a phial, and poured oil of vitriol upon it, adopting at the same time the usual apparatus for obtaining air, he observed that a permanent cloud was formed by the vapour issuing out from the mouth of the tube, which he attributed to the attachment of the acid to the aqueous moisture of the atmosphere. The moment that water came

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came in contact with this air, its surface became opaque and white by a stony film, which retarded the ascent of the water, till the air insinuating itself through the pores and cracks of the crust, the water necessarily rose as the air diminished; and breaking the crust, presented a new surface to the air, which was immediately covered with another crust. Thus one stony incrustation was formed after another till every particle of the air was united to the water; and the different films being collected and dried, formed a white powdery substance, generally a little acid to the taste; but when washed in much pure water, perfectly insipid. The property of corroding glass he found to belong to the fluor acid air only when hot. From some other experiments he concluded, that the fluor acid air was the same with what he had formerly obtained from vitriolic acid: but the experiments made since that time by various chemists, have now convinced him that it is an acid of a nature entirely different from all others.

2d 857 Method of engraving on glass.

By means of the fluor acid, a new art has been discovered, viz. that of engraving upon glass. For this purpose a looking-glass plate is to be covered with melted wax or mastic; and when the coating becomes hard, it is to be engraved upon by a very sharp-pointed needle or other instrument of that kind. A mixture of oil of vitriol and fluor acid are then to be put upon the plate, and the whole covered with an inverted China vessel, to prevent the evaporation of the fluor acid. In two days the glass plate may be cleared of its coating, when all the traces of the needle will be found upon it.

§ 5. *Of the* Sal Sedativus, *or Acid of Borax.*

858 Found in a mineral in Germany, &c.

This is a saline substance of a very singular nature, and till lately found no where but in borax itself. Its origin in different parts of the world is related under the article Borax: but since that article was printed, we have accounts of its being discovered in a mineral of a peculiar kind found at Lunenburg near Hartz. This is frequently transparent, but sometimes also a little opaque, and strikes fire slightly with steel. It has hitherto been found only in small crystals inveloped in a gypseous matter. These generally affect the cubical form, though they are sometimes irregular, and from the truncatures frequently appear to be of different kinds. One of them had fourteen faces, six small square planes, and eight hexahedral; though all these are modifications of cubes. Mr Westrumb analized it with some difficulty; but at last found that 100 parts of the mineral contained 60 of sedative salt, ten of magnesia, and ten of calcareous earth; of clay and flint five parts, sometimes ten of iron, though frequently but five. The same acid has also been discovered in Peru, and a little in Hungary from an analysis of petroleum. This bitumen arises from a rock between Pecklenicza and Moscowina. It seems at first to be white, but soon grows black by exposure to the air. It was analysed by professor Winterl, who found it to contain a transparent oil in a butyraceous form, and a true sedative salt, united with the oil by means of an excess of phlogiston. The sedative salt was first discovered by Bechr, and afterwards more accurately described by Homberg; but its nature was at first very much misunderstood, being named the *narcotic salt of vitriol*, on account of the vitriolic acid used in separating it from the borax. From this it is separable either by sublimation or crystallization. The method by sublimation is that recommended by Homberg. His process consists in mixing green vitriol with borax, dissolving them in water, filtering the solution, and evaporating till a pellicle appears: the liquor is then to be put into a small glass alembic, and the sublimation promoted till only a dry matter remains in the cucurbit. During this operation, the liquor passes into the receiver; but the internal surface of the capital is covered with a saline matter forming very small, thin, laminated crystals, very shining, and very light. This is the sedative salt. The capital is then to be unluted, and the adhering salt swept off with a feather; the part of the liquor which passed last into the receiver, is to be poured on the dry matter in the cucurbit; and a new sublimation is to be promoted as before, by distilling till the matter in the cucurbit is dry. These operations are to be frequently repeated in the same manner, till no more sedative salt can be obtained.

2d 858 How prepared from borax.

To obtain the sedative salt by crystallization, borax is to be dissolved in hot water; and to this solution any one of the three mineral acids is to be gradually added, by a little at a time, till the liquor be saturated, and even have an excess of acid, according to Mr Beaumé's process. The liquor is then to be left in a cold place; and a great number of small, shining, laminated crystals will be formed; these must be washed with a little very cold water, and drained upon brown paper. The sedative salt obtained by this process is somewhat denser than that obtained by sublimation; the latter being so light that 72 grains are sufficient to fill a large phial.

Sedative salt, though thus capable of being once sublimed, is not, however, volatile; for it arises only by means of the water of its crystallization; and when it has once lost its water by drying, it cannot be raised into vapours by the most violent fire, but remains fixed, and melts into a vitreous matter like borax itself. This glass is soluble in water; and then becomes sedative salt again. A great quantity of water is required to dissolve the sedative salt, and much more of cold than of boiling water; whence it is crystallizable by cold, as it also is by evaporation; a singular property, which scarce belongs to any other known salt. 859 Fixed in the fire.

This substance has not an *acid*, but a somewhat bitterish, taste, accompanied with a slight impression of coolness. It nevertheless unites with alkaline salts as acids do, and forms with them neutral salts. It is soluble in spirit of wine, to which it communicates the property of burning with a green flame. It makes no change on the blue colour of vegetables, as other acids do. It expels the other acids from their bases, when distilled with a strong heat; though these are all capable of expelling it in the cold, the acid of vinegar not excepted. 860 Its properties.

The composition of sedative salt is very much unknown, as no means sufficient for its decomposition have hitherto been found out. Mr Bourdelin, who made many experiments on this salt, found that it was unalterable by treatment with inflammable matters, with sulphur, with mineral acids disengaged, or united with metallic substances, and with spirit of wine. He could 861 Mr Bourdelin's experiments.

Sal sedativus and its combinations.

could only perceive some marks of an inflammable matter, and a little marine acid. The former discovered itself by its communicating a sulphureous smell to the vitriolic acid employed, and the latter by a white precipitate formed in a solution of mercury in the nitrous acid, by the liquor which came over on distilling the salt with powdered charcoal.

862 Mr Cadet's experiments.

Mr Cadet, in the Memoirs of the Royal Academy of Sciences for 1766, has given an account of some experiments made by him on borax and its acid: from which he infers (1). That the acid contained in borax itself is the marine, and not sedative, salt. (2.) That it is the marine, he proves by having made a corrosive sublimate with this acid and *mercurius precipitatus per se*. That sedative salt does not enter the composition of borax itself, he proves, by the impossibility of recomposing borax from uniting the sedative salt with fossile alkali. The salt so produced, he owns, is very like borax, but unfit for the purposes of soldering metals as borax is. He therefore thinks, that, in the decomposition of borax, the principles of the salt are somewhat changed, by the addition of that acid which extricates the sedative salt; and that this salt is composed of the marine acid originally existing in the borax, of the vitriolic acid employed in the operation, and of a vitrescible earth. (If this is true, then sedative salt either cannot be procured by any other acid than the vitriolic, or it must have different properties according to the acid which procures it.) The vitrescible earth, he says, is that which separates from borax during its solution in water, and which abounds more in the unrefined than refined borax, and which he thinks consists of a calx of copper, having obtained a regulus of copper from it. As he has never been able, however, to compose borax by the union of these ingredients, his experiments are by no means decisive. Mr Beaumé has asserted that it is always produced by rancid oils; but Dr Black thinks his proofs by no means satisfactory.

Sedative Salt COMBINED,

I. *With Vegetable Alkali.* This salt forms a compound very much resembling borax itself in quality; but in what respects it differs from, or how far it is applicable to, the purposes of borax, hath not yet been determined.

863 Borax.

II. *With Mineral Alkali.* This salt has generally been thought to recompose borax: and though Mr Cadet has denied this, yet as his experiments are hitherto imperfect and unsupported, we shall here give the history of that salt, as far as it is yet known.

This salt is prepared in the East Indies. It is said, that from certain hills in these countries there runs a green saline liquor, which is received in pits lined with clay, and suffered to evaporate with the sun's heat; that a bluish mud which the liquor brings along with it is frequently stirred up, and a bituminous matter, which floats upon the surface, taken off; that when the whole is reduced to a thick consistence, some melted fat is mixed, the matter covered with vegetable substances and a thin coat of clay; and that when the salt has crystallized, it is separated from the earth by a sieve. In the same countries is found native the mineral alkali in considerable quantity; sometimes tolerably pure, at other times blended with heterogeneous matters of various kinds. This alkali appears to exist in borax, as a Glauber's salt may be formed from a combination of borax with vitriolic acid. For a further account See BORAX.

864 Refined.

Borax, when imported from the East Indies, consists of small, yellow, and glutinous crystals. It is refined, some say, by dissolving it in lime-water; others, in alkaline lixivia, or in a lixivium of caustic alkali; and by others, in alum-water. Refined borax consists of large eight-sided crystals, each of which is composed of small, soft, and bitterish scales. It has been said that crystals of this size can by no means be obtained by dissolving unrefined borax in common water; that the crystals obtained in this way are extremely small, and differ considerably from the refined borax of the shops; insomuch that Cramer calls the large crystals, not a purified, but an adulterated borax. When dissolved in lime-water, the borax shoots into larger crystals; and largest of all, when the vessel is covered, and a gentle warmth continued during the crystallization. All this, however, is denied by Dr Black; who says, that in order to accomplish the purification, we have only to dissolve the impure borax in hot water; to separate the impurities by filtration, after which the salt shoots into the crystals we commonly see. During the dissolution, borax appears glutinous, and adheres in part to the bottom of the vessel. From this glutinous quality, peculiar to borax among the salts, it is used by dyers for giving a gloss to silks.

865 Its properties.

All acids dissolve borax slowly, and without effervescence. It precipitates from them most, but not all, metallic substances; along with which a considerable part of the borax is generally deposited. It does not absorb the marine acid of luna cornea, or of mercury sublimate. It melts upon the surface of the former without uniting, and suffers the latter to rise unchanged: the borax in both cases becomes coloured; in the first, milky with red streaks; in the latter, amethyst or purple. Mixed with sal ammoniac, it extricates the volatile alkali, and retains the acid; but mixed with a combination of the marine acid with calcareous earths, it unites with the earth, and extricates the acid. It extricates the acid of nitre without seeming to unite with the alkaline basis of that salt; nor does it mingle in fusion with the common fixed alkaline salts, the borax flowing distinct upon their surface. A mixture of borax with twice its weight of tartar, dissolves in one sixth of the quantity of water that would be necessary to dissolve them separately: the liquor yields, on inspissation, a viscous, tenacious mass like glue; which refuses to crystallize, and which deliquates in the air. Borax affords likewise a glutinous compound with the other acids, except the vitriolic; whence this last is generally preferred for making the sedative salt. It proves most glutinous with the vegetable, and least with the marine. With oils, both expressed and distilled, it forms a milky, semi-saponaceous compound. It partially dissolves in spirit of wine. In conjunction with any acid, it tinges the flame of burning matters green; the precipitate thrown down by it from metallic solutions has this effect. It does not deflagrate with nitre. Fused with inflammable matters, it yields nothing sulphureous, as those salts do which

Acetous acid and its combinations.

which contain vitriolic acid. By repeatedly moiſtening it when conſiderably heated, it may be entirely ſublimed.

Borax retains a good quantity of water in its cryſtals; by which it melts and ſwells up in a heat inſufficient to vitrify it. It is then ſpongy and light, like calcined alum; but, on increaſing the fire, it flows like water.

§ 6. *Of the* Acetous *Acid and its Combinations.*

867 How procured.

THIS acid is plentifully obtained from all vinous liquors, by a fermentation of a particular kind, (ſee FERMENTATION, and VINEGAR.) It appears firſt in the form of an acid liquor, more or leſs deeply coloured, as the vinegar is more or leſs pure. By diſtillation in a common copper-ſtill, with a pewter head and worm, this acid may be ſeparated from many of its oily and impure parts. Diſtilled vinegar is a purer but not a ſtronger acid than the vinegar itſelf; for the acid is originally leſs volatile than water, though, by certain operations, it becomes more ſo. After vinegar has been diſtilled to about $\frac{1}{10}$ of its original bulk, it is ſtill very acid, but thick and black. This matter continues to yield, by diſtillation, a ſtrong acid ſpirit, but tainted with an empyreumatic oil. If the diſtillation is continued, a thick black oil continues to come over; and at laſt ſome volatile alkali, as in the diſtillation of animal ſubſtances. The caput mortuum left in the diſtilling veſſel, being calcined in an open fire, and afterwards lixiviated, yields ſome fixed alkaline ſalt.

Acetous Acid COMBINED,

868 Sal diureticus.

I. *With Vegetable Alkali.* The produce of this combination is the *terra foliata tartari*, or ſal diureticus of the ſhops; but to prepare this ſalt of a fine white flaky appearance, which is neceſſary for ſalt, is a matter of ſome difficulty. The beſt method of performing this operation is, after having ſaturated the alkali with the vinegar, which requires about 15 parts of common diſtilled vinegar to one of alkali, to evaporate the liquor to dryneſs; then melt the ſaline maſs which remains with a gentle heat; after which it is to be diſſolved in water, then filtered, and again evaporated to dryneſs. If it is now diſſolved in ſpirit of wine, and the liquid abſtracted by diſtillation, the remaining maſs being melted a ſecond time, will, on cooling, have the flaky appearance deſired.

A good deal of caution is neceſſary in the firſt melting; for the acetous acid is eaſily diſſipable, even when combined with fixed alkali, by fire. It is proper, therefore, that, when the ſalt is melted, a little ſhould be occaſionally taken out, and put into water; and when it readily parts with its blackneſs to the water, muſt then be removed from the fire. The ſalt, when made, has a very ſtrong attraction for water, inſomuch that it is not eaſily preſerved, even when put into glaſs bottles. To keep it from deliquating, Dr Black, therefore, recommends the corks to be covered with ſome bituminous matter; otherwiſe they would tranſmit moiſture enough to make the ſalt deliquate.

869 Acetous acid with foſſile alkali.

II. *With Foſſile Alkali.* This alkali, combined with the acetous acid, forms a ſalt whoſe properties are not well known. Dr Lewis affirms, that it is nearly ſimilar to the terra foliata tartari. The author of the Chemical Dictionary, again, maintains it to be quite different: particularly that it cryſtallizes well, and is not deliqueſcent in the air; whereas the former cannot be cryſtallized; and even when obtained in a dry form, unleſs great care is taken to exclude the air, will preſently deliquate.

870 Vegetable ammoniac.

III. *With Volatile Alkali.* This combination produces a ſalt ſo exceedingly deliqueſcent, that it cannot be procured in a dry form without the greateſt difficulty. In a liquid ſtate, it is well known in medicine, as a ſudorific, by the name of *ſpiritus mindereri*. It may, however, be procured in a dry form, by mixing equal parts of vitriolic ſal ammoniac and terra foliata tartari, and ſubliming the mixture with a very gentle heat. When the ſalt is once procured, the utmoſt care is requiſite to preſerve it from the air.

871 Anomalous ſalts.

IV. *With Earths.* Combinations of this kind are but little known. With the calcareous and argillaceous earths compounds of an aſtringent nature are formed. According to the author of the Chemical Dictionary, the ſalt reſulting from a combination of vinegar with calcareous earth eaſily cryſtallizes, and does not deliquate. With magneſia the acetous acid does not cryſtallize; but, when inſpiſſated, forms a tough maſs, of which two drachms, or two and a half, are a briſk purgative.

872 Diſtilled verdegris.

V. *With Copper.* Upon this metal the acid of vinegar does not act briſkly, until it is partly at leaſt calcined. If the copper is previouſly diſſolved in a mineral acid, and then precipitated, the calx will be readily diſſolved by the acetous acid. The ſolution is of a green colour, and beautiful green cryſtals may be obtained from it. The ſolution, however, is much more eaſily effected, by employing verdegris, which is copper already united with a kind of acetous or tartareous acid, and very readily diſſolves in vinegar. The cryſtals obtained by this proceſs are uſed in painting, under the name of *diſtilled verdegris*.

The moſt ready, and in all probability the cheapeſt, method of preparing the cryſtals of verdegris is that propoſed by Mr Wenzel, by mixing together the ſolutions of ſugar of lead and blue vitriol, when an exchange of baſes takes place; the lead being inſtantly precipitated by the vitriolic acid, and the acetous acid uniting with the copper. From 15 ounces and two drachms of ſugar of lead with twelve ounces of blue vitriol, five ounces of the cryſtals were obtained. The precipitate of lead, though waſhed ſeveral times with water, never loſt its green colour. It may either be uſed, he ſays, in this ſtate, as a green pigment, or it may be made perfectly white by digeſtion in dilute nitrous acid.

873 Iron liquor for printing cloth.

VI. *With Iron.* Vinegar acts very readily upon iron, and diſſolves it into a very brown and almoſt black liquor, which does not eaſily cryſtallize, but, if inſpiſſated, runs per deliquium. This liquor is employed in the printing of linens, calicoes, &c. being found to ſtrike a finer black with madder, and to injure the cloth leſs, than ſolutions of iron in the other acids.

874 Lead.

VII. *With Lead.* The acetous acid diſſolves lead in its metallic ſtate very ſparingly; but if the metal is calcined, it acts upon it very ſtrongly. Even after lead is melted into glaſs, the acetous acid will receive a ſtrong impregnation from it; and hence it is dangerous to

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to put vinegar into ſuch earthen veſſels as are glazed with lead. In the metallic ſtate, only a drachm of lead can be diſſolved in eight ounces of diſtilled vinegar.

875 Ceruſs. If lead is expoſed to the vapours of warm vinegar, it is corroded into a kind of calx, which is uſed in great quantities in painting, and is known by the name of *ceruſs* or *white lead*. The preparation of this pigment has become a diſtinct trade, and is practiſed in ſome places in Britain where lead is procurable at the loweſt price. The proceſs for making ceruſs is thus given by the author of the Chemical Dictionary.

"To make ceruſs, leaden plates rolled ſpirally, ſo that the ſpace of an inch ſhall be left between each circumvolution, muſt be placed vertically in earthen pots of a proper ſize, containing ſome good vinegar. Theſe leaden rolls ought to be ſo ſupported in the pots that they do not touch the vinegar, but that the acid vapour may circulate freely betwixt the circumvolutions. The pots are to be covered, and placed in a bed of dung, or in a ſand-bath, by which a gentle heat may be applied. The acid of vinegar being thus reduced into vapour, eaſily attaches itſelf to the ſurface of theſe plates, penetrates them, and is impregnated with the metal, which it reduces to a beautiful white powder, called *ceruſs*. When a ſufficient quantity of it is collected on the plates, the rolls are taken out of the pots, and unfolded; the ceruſs is then taken off, and they are again rolled up, that the operation may be repeated.

"In this operation, the acid being overcharged with lead, this metal is not properly in a ſaline ſtate; hence ceruſs is not in cryſtals, nor is ſoluble in water: but a ſaline property would render it unfit for painting, in which it is chiefly employed."

876 Obſervations on the proceſs for ceruſs. Though this proceſs may in general be juſt, yet there are certainly ſome particulars neceſſary to make ceruſs of a proper colour, which this author has omitted; for though we have carefully treated thin plates of lead in the manner he directs, yet the calx always turned out of a dirty grey colour. It is probable, therefore, that after the lead has been corroded by the ſteam of vinegar, it may be waſhed with water ſlightly impregnated with the vitriolic and nitrous acids.

This preparation is the only white hitherto found fit for painting in oil: but the diſcovery of another would be very deſirable, not only from the faults of ceruſs as a paint, but alſo from its injuring the health of perſons employed in its manufacture, by affecting them with a ſevere colic; which lead, and all its preparations, frequently occaſion.

877 Sugar of lead. If diſtilled vinegar is poured on white lead, it will diſſolve it in much greater quantity than either the lead in its metallic form, or any of its calces. This ſolution filtered and evaporated, ſhoots into ſmall cryſtals of an auſtere ſweetiſh taſte called *ſugar of lead*. Theſe are uſed in dyeing, and externally in medicines. They have been even given internally for ſpitting of blood. This they will very certainly cure; but at the ſame time they as certainly kill the patient by bringing on other diſeaſes. If theſe cryſtals are repeatedly diſſolved in freſh acids, and the ſolutions evaporated, an oily kind of ſubſtance will at laſt be obtained, which can ſcarcely be dried.

From all the metallic combinations of the acetous acid, it may be recovered in an exceedingly concentrated form, by ſimple diſtillation, ſugar of lead only excepted. If this ſubſtance is diſtilled in a retort with a ſtrong heat, it hath been ſaid that an inflammable ſpirit, and not an acid comes over; but this is denied by Dr Black. 878 Inflammable ſpirit from ſugar of lead.

VIII. *With Tin.* The combination of acetous acid with tin is ſo little known, that many have doubted whether diſtilled vinegar is capable of diſſolving tin or not. Dr Lewis obſerves, "That plates of pure tin put into common vinegar begun in a few hours to be corroded, without the application of heat. By degrees a portion of the metal was taken up by the acid, but did not ſeem to be perfectly diſſolved, the liquor appearing quite opaque and turbid, and depoſiting great part of the corroded tin to the bottom, in a whitiſh powder. A part of the tin, if not truly diſſolved, is exquiſitely divided in the liquor; for, after ſtanding many days and after paſſing through a filter, ſo much remained ſuſpended as to give a whitiſhneſs and opacity to the fluid. Acid juices of fruits, ſubſtituted to the vinegar, exhibited the ſame phenomena. Theſe experiments are not fully concluſive for the real ſolubility of tin in theſe acids, with regard to the purpoſes for which chemiſts have wanted ſuch a ſolution: but they prove what is more important; that tin, or tinned veſſels, however pure the tin be, will give a metallic impregnation to light vegetable acids ſuffered to ſtand in them for a few hours." 879 Tin. 880 Dr Lewis's experiments concerning the ſolubility of tin.

With regard to other metallic ſubſtances, neither the degree of attraction which the acetous acid has for them, nor the nature of the compounds formed by the union of it with ſuch ſubſtances, are known; only, that as much of the reguline part of antimony is diſſolved in this acid as to give it a violent emetic quality. See *Regulus of Antimony*.

Concentration of the *Acetous Acid*.

Common vinegar, as any other weak acid, may be advantageouſly concentrated by froſt; as alſo may its ſpirit or the diſtilled vinegar of the ſhops: but as the cold, in this country, is ſeldom or never ſo intenſe as to freeze vinegar, this method of concentration cannot be made uſe of here. If diſtilled vinegar be ſet in a water-bath, the moſt aqueous part will ariſe, and leave the more concentrated acid behind. This method, however, is tedious, and no great degree of concentration can be produced, even when the operation is carried to its utmoſt length. A much more concentrated acid may be obtained by diſtilling in a retort the cryſtals of copper, mentioned (n° 872) under the name of *diſtilled verdegris*. A very ſtrong acid may thus be obtained, which has a very pungent ſmell, almoſt as ſuffocating as volatile ſulphureous acid. The Count de Lauraguais diſcovered that this ſpirit, if heated in a wide-mouthed pan, would take fire on the contact of flaming ſubſtances, and burn entirely away, like ſpirit of wine, without any reſiduum. The ſame nobleman alſo obſerved, that this ſpirit, when well concentrated, eaſily cryſtallizes without addition. 881 Concentrated vinegar. 882 Salt of vinegar.

This

Acetous acid and its combinations.

This may seem to be the most proper method of obtaining the acetous acid in its greatest degree of strength and purity: but as the process requires a very strong heat to be used towards the end of the operation, it is probable that part of the acetous acid may be by that means entirely decomposed. It would seem preferable, therefore, to decompose pure terra foliata tartari by means of the vitriolic acid, in the same manner as nitre or sea-salt are decomposed for obtaining their acids. In this case, indeed, the acetous acid might be a little mixed with the vitriolic; but that could easily be separated by a second distillation. A still better method of preparing the acid seems to be by distilling sugar of lead with oil of vitriol. The proportion used by M. Lorenzen of Copenhagen, is three ounces of vitriolic acid to eight of the sugar of lead. Mr Dollfuss recommends two parts of sugar of lead to one of vitriolic acid.

883 Dr Priestley's experiments.

Dr Priestley, who gives us several experiments on the vegetable acid when reduced to the form of air, mentions his being easily able to expel it from some exceedingly strong concentrated vinegar, by means of heat alone. This seems somewhat contrary to the count de Lauraguais's observation of the disposition of the *spirit of verdegris*, as it is commonly called, to crystallize: but a still greater difference is, that the vegetable acid air extinguished a candle, when according to the Count's observation, it ought to have been inflammable. The most curious property observed by Dr Priestley is, that the vegetable acid air being imbibed by oil olive, the oil was rendered less viscid, and clearer, *almost like an essential oil*. This is an useful hint; and, if pursued, might lead to important discoveries.

Acetous acid combined with *Inflammable Matter*.

884 Vegetable ether.

The only method yet known, of combining acetous acid with the principle of inflammability, is by mixing together equal parts of the strongly concentrated acid called *spirit of verdegris*, and spirit of wine. The result is, a new kind of *ether*, similar to the vitriolic, nitrous, and marine. This ether, however, retains some of the acidity and peculiar smell of the vinegar. By rectification with fixed alkali, it may be freed from this acidity, and then smells more like true ether, but still retaining something of the smell, not of the acid, but the inflammable part of the vinegar.

In this process a greater quantity of ether is obtained than by employing the vitriolic acid: which shows that the vegetable acid is essentially fitter to produce ether than the vitriolic. For making the acetous ether readily, Mr Dollfuss recommends eight ounces of sugar of lead dried by a very gentle heat, until it loses the water of crystallization, when it will weigh five ounces and six drachms. It is then to be put into a glass retort and a mixture of five ounces of vitriolic acid, with eight of spirit of wine, poured upon it, and the whole distilled with a very gentle fire. The first ounce that passes over will be dulcified acetous acid, the next almost all ether, and the third ether in its purest state.

An ether may also be obtained from vinegar of wood. To make it, the most concentrated acid of this kind is to be made use of. For this purpose an empyreumatic acid must first be distilled from beech-wood, and then rectified by a second distillation. Three pounds of this require for their saturation five ounces of purified alkali, which by evaporation and fusion affords three ounces and a quarter of terra foliata tartari. From this, one ounce six drachms of concentrated acid are obtained; and this, on being mixed with an equal quantity of alcohol, yields two ounces one drachm and a half of genuine ether.

Acid of tartar and its combinations

§ 7. *Of the Acid of* Tartar.

885 tartar.

Tartar is a substance thrown off from wine, after it is put into casks to depurate. The more tartar that is separated, the more smooth and palatable the wine is. This substance forms a thick hard crust on the sides of the casks: and, as part of the fine dregs of the wine adhere to it, the tartar of the white wines is of a greyish white colour, called *white tartar*; and that of red wine has a red colour, and is called *red tartar*.

886 Cream of tartar.

When separated from the casks on which it is formed, tartar is mixed with much heterogeneous matter; from which, for the purposes of medicine and chemistry, it requires to be purified. This purification is performed at Montpelier; and consists first in boiling the tartar in water, filtrating the solution, and allowing the salt to crystallize, which it very soon does; as tartar requires nearly twenty times its weight of water to dissolve it.

The crystals of tartar obtained by this operation are far from being perfectly pure; and therefore they are again boiled in water, with an addition of clay, which absorbs the colouring matter; and thus, on a second crystallization, a very pure and white salt is obtained. These crystals are called *cream*, or *crystals of tartar*; and are commonly sold under these names.

Dr Black observes, that in the purification of tartar, it is necessary to add some earthy substances, in order to absorb or carry down the colour. Macquer thinks that these substances unite in part with the tartar, and render it more soluble, but they have little disposition to unite with acids; they are the purer kinds of clay, and promote the complete deposition of its impurities; so that in the management of wines it is necessary to add certain powdery substances which have some weight, and fall to the bottom readily; and which, in falling, carry down a number of particles that would otherwise float in the liquor for a long time, being so light that they could hardly be made to subside; but the particles of clay adhering to them increase their gravity; and probably it answers the same purpose in the refinement of tartar.

To obtain the pure Acid of *Tartar*.

887 Scheele's analysis of cream of tartar.

For a long time the cream or crystals of tartar were considered as the purest acid which could be obtained from this substance; but, in the year 1770, an analysis of tartar was published in the Swedish transactions, by Mr Scheele. His method of decomposing the salt was, to dissolve it in a sufficient quantity of boiling water, then to add chalk in fine powder till the effervescence ceased. A copious precipitation ensued; and the remaining liquor being evaporated;

Acid of tartar and its combinations.

porated, afforded a ſoluble tartar. This proved that cream of tartar is not, as was commonly ſuppoſed, an acid of a peculiar kind, joined with a great deal of earthy impurities; but really a compound ſalt, containing an alkali joined with an acid; and that the alkali produced from burnt tartar is not generated in the fire, but pre-exiſtent in the ſalt.

The whole ſediment contained in this experiment, is the calcareous earth combined with the acid of tartar, which may juſtly be called *ſelenites tartareus*. If ſome diluted vitriolic acid is poured upon this ſelenites tartareus, the vitriolic acid expels the acid of tartar, forming a true ſelenite with the earth, while the liquor contains the pure acid of tartar. By inſpiſſation this acid may be made ſtronger, and even formed into ſmall white cryſtals, which do not deliquate in the air. A particular ſpecies of tartar extracted from ſorrel hath
888 Eſſential ſals of lemon. been ſold for taking ſpots out of clothes, under the name of *eſſential ſalt of lemons*, and which is now diſcovered to be the ſame with the acid of ſugar.

This experiment was ſoon after confirmed by Dr Black; who farther obſerved, that if quicklime was uſed inſtead of chalk, the whole acid would be abſorbed by the lime, and the remaining liquor, inſtead of being a ſolution of ſoluble tartar, would be a cauſtic lixivium. The moſt ready method, however, of procuring the pure acid of tartar ſeems to be that recommended by Mr Schiller in the Chemical Annals for 1787. One pound of cream of tartar is to be boiled in five or ſix pounds of water, and a quartar of a pound of oil of vitriol added by little and little, by which means a perfect ſolution will be obtained. By continuing the boiling, all the vitriolated tartar is precipitated. When the liquor is evaporated to one half, it muſt be filtered; and if, on the renewal of the boiling, any thing farther is precipitated, the filtration is to be repeated. The clear liquor is then to be reduced to the conſiſtence of a ſyrup, and ſet in a temperate, or rather a warm place, when very fine cryſtals will be formed, and as much acid obtained as is equal in weight to half the cream of tartar employed. If too ſmall a quantity of vitriolic acid has been employed, the undecompoſed cream of tartar falls along with the vitriolated tartar.

Acid of Tartar COMBINED,

889 Soluble tartar. I. *With Vegtable Alkali.* If the pure acid of tartar be combined with this alkali to the point of ſaturation, a neutral ſalt is produced, which deliquates in the air, and is not eaſily cryſtallized, unleſs the liquor be kept warm, and likewiſe be ſomewhat alkaline. This ſalt, called *ſoluble tartar*, is uſed in medicine as a purgative; but as its deliqueſcence does not admit of its being kept in a cryſtalline form, it is always ſold in powder. Hence thoſe who prepare ſoluble tartar, take no further trouble than merely to rub one part of fixed alkaline ſalt with three of cream of tartar, which renders the compound ſufficiently neutral, and anſwers all the purpoſes of medicine. Dr Black informs us, that in medical preſcriptions, where ſoluble tartar is ordered as a purgative along with a decoction of tamarinds, the acid of the latter will decompoſe the ſoluble tartar, and thus the preſcription may perhaps be rendered ineffectual. The ſaline mixture uſed in fevers is nothing but a tartarus ſolubilis in ſolution.

According to Mr Scheele, cream of tartar may be recompoſed from the pure acid and alkali in the following manner: "Upon fixed vegetable alkali pour a ſolution of the acid of tartar. Continue this till the effervescence is over; the fluid will then be tranſparent; but if more of the acid is added, it will become turbid and white, and ſmall cryſtals like white ſand will be formed in it. Theſe cryſtals are a perfect cream of tartar. 890 Regenerated cream of tartar.

Upon theſe principles, another method of decompoſing cream of tartar might be tried; namely, adding to it as much oil of vitriol as would ſaturate the alkali, then diſſolving and cryſtallizing the ſalt: but, by this method, there would be danger of the acid being adulterated with vitriolic tartar.

II. *With Foſſile Alkali.* The ſalt produced from an union of cream of tartar with foſſile alkali, has been long known under the names of *Siegnette's ſalt*, *ſal Rupellenſis*, or *Rochelle ſalt*; but as the cream of tartar is now diſcovered to be not a pure acid, but adulterated with a portion of ſoluble tartar, poſſibly ſome differences might be obſerved if the pure acid was uſed. 891 Siegnette's or Rochelle ſalt.

This ſalt was firſt invented and brought into vogue by one Seignette, an apothecary at Rochelle, who kept the compoſition a ſecret as long as he could. Meſſrs Boylduc and Geoffroy afterwards diſcovered and publiſhed its compoſition.

To prepare this ſalt, cryſtals of mineral alkali are to be diſſolved in hot water, and powdered cream of tartar thrown in as long as any effervescence ariſes. For the better cryſtallization of the ſalt, the alkali ought to prevail. The liquor muſt then be filtered and evaporated, and very fine large cryſtals may be obtained by cold, each of which is the half of a polygonous priſm cut in the direction of its axis. This ſection, which forms a face much larger than the reſt, is, like them, a regular rectangle, diſtinguiſhable from the others, not only by its breadth, but alſo by two diſtinct diagonal lines which interſect each other in the middle. The following method of preparing Siegnette's ſalt, recommended by Mr Scheele, ſeems preferable to any other on account of its eaſe and cheapneſs. Thirty ſix ounces of cryſtals of tartar are to be ſaturated with potaſh, and eleven ounces of common ſalt diſſolved in the ley. When it is grown cold, and the vitriolated tartar has ſubſided to the bottom, it is filtered and evaporated till a pellicle appears; the two firſt cryſtallizations yield a fine Seignette's ſalt; the third contains ſome digeſtive ſalt; and the fourth is entirely compoſed of it. The reaſon of this formation of Seignette's ſalt is, that the vegetable alkali has a greater attraction for acids than the mineral, and therefore decompoſes the ſea-ſalt, whoſe baſis is then at liberty to combine with the acid of tartar; while the ſtronger marine acid takes the vegetable alkali.—A ſalt of the ſame kind will be produced by adding Glauber's ſalt inſtead of common ſea-ſalt.

III. *With Volatile Alkali.* With regard to this combination, all we know as yet is, that if the alkali is over-ſaturated with acid, a cream of tartar, almoſt as difficult of ſolution as that of fixed alkali, will be obtained. When the ſaturation has been pretty exact, a beautiful ſalt, compoſed of four ſided pyramids, and which does not deliquate in the air, is produced. It is inſtantly decompounded, and emits a pungent volatile ſmell on being mixed with fixed alkali. 892 Cream of tartar.

IV.

Acid of tartar and its combinations.

IV. *With Earths.* All that is as yet known concerning theſe combinations, is, that with the calcareous earth a compound not eaſily ſoluble in water is formed. The other properties of this ſubſtance, and the nature of combinations of tartareous acid with other earths, are entirely unknown.

893 Selenites tartareous.

894 A fine green colour.

V. *With Copper.* In its metallic ſtate, cream of tartar acts but weakly on the metal, but diſſolves verdegris much more prfectly than diſtilled vinegar can. The ſolution of cream of tartar, being evaporated, does not cryſtallize, but runs into a gummy kind of matter; which, however, does not attract the moiſture of the air. It readily diſſolves in water, and makes a beautiful bluiſh green on paper, which has the property of always ſhining, as if covered with varniſh. The effects of the pure acid on this metal have not yet been tried.

895 Chalybeated tartar.

VI. *With Iron.* The effects of a combination of iron with the pure acid have not hitherto been tried. Cream of tartar diſſolves this metal into a green liquor, which being evaporated runs *per deliquium*. It has been attempted to ſubſtitute a ſolution of this kind to the liquor uſed in printing calicoes formed of iron and ſour beer; but this gave a very dull browniſh colour with madder. Poſſibly, if the pure acid was uſed, the colour might be improved. In medicine, a combination of cream of tartar with iron is uſed, and probably may be an uſeful chalybeate.

VII. *With Regulus of Antimony.* See Sect. III.

§ 8. *Of the Acid of* SUGAR.

896 Saccharine acid.

THAT ſugar contains an acid, which on diſtillation by a ſtrong fire ariſes in a liquid form, in common with that of moſt other vegetable ſubſtances, has been generally known; but how to obtain this acid in a concrete form, and to appearance as pure and cryſtallizable as the acid of tartar, we were entirely ignorant, till the appearance of a treatiſe intitled, *Diſſertatio Chemica, de acido Sacchari, auctore* Johanne Afzelio Arvidſſon, 4to, *Upſaliæ*.

Of the method of procuring, and the properties of, this new acid, we have the following account in the Edinburgh Medical Commentaries, vol. iv.

"1. To an ounce of the fineſt white ſugar in powder, in a tubulated retort, add three ounces of ſtrong ſpirit of nitre.

"2. The ſolution being finiſhed, and the phlogiſton of the ſpirit of nitre moſtly exhaled, let a receiver be properly fitted to the retort and luted, and the liquor then made to boil gently.

"3. When the ſolution has obtained a browniſh colour, add three ounces more of ſpirit of nitre, and let the ebullition be continued till the fumes of the acid are almoſt gone.

897 Chryſtals of ſaccharine acid.

"4. The liquor being at length emptied in a *larger* veſſel, and expoſed to a proper degree of cold, quadrangular priſmatic cryſtals are obſerved to form; which being collected, and dried on ſoft paper, are found to weigh about 109 grains.

"5. The remaining liquor being again boiled in the ſame retort, with two ounces of freſh ſpirit of nitre, till the red vapours begin to diſappear, and being then in the ſame manner expoſed to cryſtallize, about 43 grains of ſaline ſpiculæ are obtained.

Acid of ſugar and its combinations.

"6. To the liquid that ſtill remains, about two ounces more of ſpirit of nitre being added, and afterwards the whole being, *both by boiling and evaporation*, reduced to a dry maſs, a brown, ſaline, gelatinous kind of ſubſtance is produced, which, when thoroughly dry, is found to weigh about half a drachm.

"In the ſame manner, a ſimilar acid, we are told, may be obtained from different ſaccharine ſubſtances, as *gum-arabic, honey, &c.*; but from none in ſuch quantities, or ſo pure, as from fine ſugar."

898 Preſumption of its expelling the vitriolic acid.

This ſalt poſſeſſes ſome very ſingular properties, of which what appears to us the moſt remarkable, and which we cannot help reading with ſome degree of doubt, is, that it produces an effervſcence on being added to ſuch *alkaline, earthy, or metallic ſubſtances, as contain the vitriolic acid.* From this we ſhould be apt to think, that this acid was capable of diſlodging even the vitriolic acid from its baſis.

Acid of ſugar, being diſtilled in a retort, gives over about $\frac{3}{10}$ of its weight of water. By an intenſe heat it melts, and is partly ſublimed; leaving in the retort a dark grey maſs, of about the fifth part of the weight of the cryſtals made uſe of. The ſublimed ſalt eaſily recovers the cryſtalline form, and ſeems to have undergone no further change by ſublimation than being rendered more pure. During the diſtillation a great quantity of elaſtic vapour ruſhes out (about 100 cubic inches from half an ounce of the cryſtals), which, from the diſtilled liquor's precipitating lime-water, we may judge to be fixed air. In a ſecond ſublimation, white fumes are ſent over, which, when cold, appear to be an acid, glaſſy-coloured liquor, but cannot be again cryſtallized. "Such parts of the ſalts as adhere to the ſides and necks of the veſſels do not appear to be in the leaſt changed in the proceſs." On a third ſublimation, theſe parts produced ſuch elaſtic vapours as burſt the receiver.

899 Great acid power.

This ſingular ſalt has a conſiderable acid power; twenty grains of it giving a very conſiderable degree of acidity to a large tankard of water. It diſſolves in an equal weight of diſtilled water, but concretes on the liquor's growing cool. It is alſo ſoluble in ſpirit of wine; 100 parts of boiling ſpirit of wine diſſolving 56 of the ſaccharine cryſtals, but no more than 40 when cold. The ſolution in ſpirit of wine ſoon becomes turbid; and depoſites a mucous ſediment, in quantity about $\frac{1}{40}$ of the acid made uſe of. When cold, irregular ſcaly cryſtals are formed, which when dry are perfectly white.

900 Incredible quantity of volatile alkali ſaturated by it.

With vegetable alkali, the acid of ſugar can ſcarcely be formed into cryſtals, unleſs either the alkali or acid predominate. With mineral alkali, a ſalt very difficult of ſolution is formed. The quantity of volatile alkali ſaturated by this acid is incredible. "Six parts of a pure volatile alkali may be ſaturated with one of the acid of ſugar. The produce is a quadrangular priſmatic ſalt. With lime this acid unites ſo ſtrongly, as to be ſeparable by no other means than a ſtrong heat. What kind of a ſalt reſults from this combination we are not told; but the author is of opinion, that this ſhows the uſe of lime in the purification of ſugar, in order to abſorb the ſuperfluous acid. Being ſaturated with ſome of the *terra ponderoſa*, the acid of ſugar immediately depoſits a quantity of pellucid angular cryſtals, ſcarcely ſoluble in water. With magneſia

Acid of ſugar and its combinations.

till the ſalt appears in form of a white powder, ſoluble neither in water nor ſpirit of wine, unleſs the acid prevails. It has a ſtronger affinity with magneſia than any of the alkaline ſalts. With earth of alum, no cryſtals are obtained; but a yellow pellucid maſs, of a ſweetiſh and ſomewhat aſtringent taſte; which, in a moiſt air, liquefies, and increaſes two-thirds in weight.

901 Its effects on metals.

This acid acts upon all metals, gold, ſilver, platina, and quickſilver, not excepted, if they have been previouſly diſſolved in an acid, and then precipitated. Iron in its metallic ſtate is diſſolved in very large quantity by the saccharine acid; 45 parts of iron being ſoluble in 55 of acid. By evaporation, the liquor ſhoots into yellow priſmatic cryſtals, which are eaſily ſoluble in water. With cobalt, a quantity of yellow-coloured cryſtals are obtained, which being diſſolved in water, and ſea-ſalt added to the ſolution, form a ſympathetic ink. The elective attractions of this ſingular acid are, firſt, lime, than the *terra ponderoſa*, magneſia, vegetable alkali mineral alkali, and laſtly clays. With ſpirit of wine an ether was obtained which cannot eaſily be ſet on fire unleſs previouſly heated, and burns with a blue inſtead of a white flame.

902 Saccharine ether.

903 Whether this acid is produced from the nitrous.

Towards the concluſion of his diſſertation the author obſerves, that ſome may imagine that the acid of nitre made uſe of in theſe experiments, may have a conſiderable ſhare in the production of what he has termed *acid of ſugar*. But though he acknowledges that this acid cannot in any way be obtained but by the aſſiſtance of ſpirit of nitre, he is thoroughly convinced that it does not, in any degree, enter into its compoſition.

What occurs to us on this ſubject is, that if the acid really pre-exiſts in the ſugar, it muſt give ſome tokens of its exiſtence by mixing the ſugar with other ſubſtances beſides ſpirit of nitre. The author himſelf thinks that lime acts upon the acid part of the ſugar: from whence we are apt to conclude, that by mixing lime, in a certain proportion, with ſugar, a compound ſhould be obtained ſomewhat ſimilar to what was formed by a direct combination of lime with the pure acid. In this caſe, we might conclude that the nitrous acid produces this ſalt, by combining with the inflammable part of the ſugar, becoming thereby volatile, and flying entirely off, ſo as to leave the acid of the ſugar pure. In the diſtillation of dulcified ſpirit of nitre, however, we have an inſtance of the nitrous acid itſelf being very much altered. This muſt therefore ſuggeſt a doubt that the acid ſalt obtained in the preſent caſe is only the nitrous acid deprived of its phlogiſton, and united with ſome earthy particles.

In a treatiſe lately publiſhed by Mr Rigby, however, we are informed that ſugar itſelf may be recompoſed by uniting the acid of ſugar with phlogiſton; which aſſertion, if well founded, undoubtedly decides the diſpute in favour of the ſaccharine acid being originally contained in the ſugar. Late experiments have determined it to be the ſame with that of ſorrel; for which, as well as many other valuable acquiſitions, the ſcience of chemiſtry is indebted to Mr Scheele. Having diſſolved as much acid of ſugar in cold water as the liquor could take up, he added to this ſolution

2d 903 The ſame with the acid of ſorrel.

ſome lixivium of tartar drop by drop, waiting a little after each drop, and found the mixture, during the efferveſcence, full of ſmall cryſtals, which were genuine ſalt of wood-ſorrel. M. Klaproth having precipitated a nitrous ſolution of quickſilver with ſalt of wood-ſorrel, perfectly neutralized by vegetable alkali, obtained a white precipitate; which, when edulcorated and dried, and gently heated in a tea-ſpoon, fulminated with a noiſe not inferior to that of fulminating gold. Acid of ſugar perfectly neutralized with vegetable alkali, afforded the ſame precipitate, and fulminated in the ſame manner.

Acid of Phoſphorus and its combinations.

3d 903 Fulminating quickſilver.

§ 9. *Of the Acid of* Phosphorus.

904 Phoſphoric acid.

This acid was firſt diſcovered by Homberg in urine; afterwards by Margraaf in muſtard and cruciferous plants: M. Bochante diſcovered it in wheat; and laſtly, M. Haſſenfratz has traced it in the mineral kingdom with great attention.—He has found that phoſphorated iron is contained in all the Pruſſian blues, when not purified; but that this acid is produced by the coals employed in the proceſs, and is no conſtituent part of the tinging matter. According to him it occurs almoſt univerſally in the minerals of iron which are found in the ſlimy ſtrata of the earth, as well as thoſe which are undoubtedly modern, whether primary or ſecondary; unleſs the iron be ſo far of a metallic nature as to be attracted by the magnet, or very near that ſtate. It is afforded by the ochry ſtrata, and thoſe which contain hæmatites as well as the ſlimy kind. Into theſe it is ſuppoſed to have come by the decompoſition of vegetables; and to inveſtigate this matter he examined the hibiſcus paluſtris, ſolidago, virga aurea, antirrhinum, lunaria, ſolanum nigrum, vulgatum, ſtachys paluſtris, artemiſia Zeylandica, ruta graveolens, lycopus Europeus, carex acuta; vinca major, nepeta Pannonica, and noa Abyſſina. All theſe plants afforded the acid of wood-ſorrel and the phoſphoric acid. The quantity of the former varied from two ounces to two drachms 18 grains of acid ſalt containing ſome calcareous earth, to two drachms 24 grains in a pound of each plant; the quantity of calcareous phoſphoric ſalt being from one ounce ſix drachms 48 grains to one drachm 12 grains.—M. Haſſenfratz alſo obſerves, that the phoſphoric acid is procurable from all ſorts of iron; though in ſome it ſeems to proceed from that contained in the earth, and in others from the coals employed in the reduction.

The phoſphoric acid is alſo found by Dr Marquart to be contained in the gaſtric juice of animals. One pound four ounces of the gaſtric juice of oxen gave 10 grains of a lymphatic matter, exactly like the blood in its qualities; 16 grains and ſix-ſevenths of phoſphoric acid, which with a blow-pipe was changed into a very pure and deliqueſcent glaſs of phoſphorus; five grains of phoſphorated lime, two grains of reſin, 14 grains of ſal ammoniac, 29 grains of common ſalt, a very ſmall quantity of an extract whoſe nature was difficult to aſcertain; one pound three ounces ſix drachms and 67½ grains of water; ſo that the ſolid contents were only 166th part of the bulk.

In ſheep, the quantity of gaſtric juice was about eight ounces in quantity, of a deeper and brighter green

Acid of phosphorus and its combinations.

green than that of oxen or calves; but affording the same ingredients, though in a different proportion; though no other acid than that of phosphorus could be discovered. It was also more disposed to putrefaction. Calves furnished from four to six ounces of gastric juice, which contained very little lymph, but afforded some quantity of dry jelly, though the whole was not equal to the proper proportion of lymph. The phosphorated lime was in the usual quantity, but the disengaged phosphoric acid in a very small proportion. The lacteal acid was found in great quantity; to which, along with that of phosphorus, our author supposes the property of curdling the milk in the animal's stomach to be owing.

The phosphoric acid has also been found in very large quantity in the calcareous stones of Andalusia; and Mr Klaproth has found the same combined with calcareous earth in a kind of beryl, crystallized in hexahedral prisms, called by M. Verner *apatit*.—Formerly the best method of obtaining it was from urine, where it is contained in very considerable quantity in combination with the volatile alkali, and forming a salt called the *microcosmic*, or *essential salt of urine*.

905 Microcosmic salt, how procured.

To procure this, a large quantity of urine is to be evaporated to the consistence of a thin syrup; which, being set in a cold place, will yield, in three or four weeks, foul brown-coloured crystals, which are the microcosmic salt, mixed with the marine, and other salts of urine. These crystals are to be dissolved in hot water; the solution filtered whilst it continues hot, and set to crystallize again; and the solution, filtration, and crystallization, repeated till the salt becomes pure and white. In all the crystallizations the microcosmic salt shoots first, and is easily distinguished and separated from the others. If the urine which remains after the first crystallization be further evaporated, and again set in the cold, it will yield more crystals; but browner and more impure than the former; and therefore requiring to be purified by themselves. From 20 gallons of urine may be obtained four ounces of pure salt; a considerable part being still left in the residuum.

In these operations the heat ought to be gentle, and the vessels either of glass or compact stone-ware. Urine being evaporated in a copper vessel, afforded only a green solution of that metal.

906 Mr Margraaf's experiments.

Concerning the nature of the microcosmic salt obtained by the above process, Mr Margraaf gives the following account in the Berlin memoirs for 1746.

"Sixteen ounces of the salt, distilled in a glass retort, in a heat gradually raised, gave over eight ounces of a volatile urinous spirit, resembling that made from sal ammoniac by quicklime. The residuum was a porous brittle mass, weighing eight ounces. This, urged with a stronger fire in a crucible, bubbled and frothed much, and at length sunk down into the appearance of glass, without seeming to suffer any further diminution of its weight in the most vehement heat.

The vitreous matter dissolved in twice or thrice its quantity of water, into a clear, transparent, acid liquor, somewhat thick, not ill resembling in consistence concentrated oil of vitriol. This liquor totally corroded zinc into a white powder, which, being diluted with water, appeared in great part to dissolve, fixed alkalies occasioning a plentiful precipitation. It acted powerfully upon iron, with some effervescence; and changed the metal into a kind of muddy substance inclining to bluish, in part soluble in water like the preceding. It dissolved likewise a portion of regulus of antimony, and extracted a red tincture from cobalt. On lead and tin it had very little action. Copper it corroded but slightly. On bismuth, silver, and gold, it had no effect at all, either by strong digestion, or a boiling heat. Nor did the adding of a considerable portion of nitrous acid enable it to act upon gold.

"The vitreous salt in its dry form, melted with metallic bodies with a strong fire, acts upon them more powerfully. In each of the following experiments, two drachms of the salt were taken to two scruples of the metal reduced to small parts. (1.) Gold communicated a purple colour to the vitreous salt; on weighing the metal, however, its diminution was not considerable. (2.) Silver lost four grains, or $\frac{1}{10}$; and rendered the salt yellowish, and moderately opaque. (3.) Copper lost only two grains, or $\frac{1}{20}$, though the salt was tinged of a deep green colour. It seemed as if a portion of the salt had been retained by the metal, which, after the fusion, was found to be whiter and more brittle than before. (4.) During the fusion with iron, flashes like lightning were continually thrown out; a phosphorus being generated from the combination of the acid with the inflammable principle of the iron. Great part of the mixture rises up in froth; which, when cold, appears a vitreous scoria, covered on the surface with a kind of metallic skin, which, on being rubbed, changes its green colour to a yellowish. The rest of the iron remains at the bottom of the crucible, half melted, half vitrified, and spongy. (5.) Tin lost 18 grains, or nearly one-half its weight, and rendered the salt whitish; the remaining metal being at the same time remarkably changed. It was all over leafy and brilliant, very brittle, internally like zinc. Laid on burning coals, it first began to melt, then burnt like zinc, or phosphorus. (6.) Lead lost 16 grains, and gave the same whitish colour to the scoriæ that tin does. The remaining lead was in like manner inflammable, but burnt less vehemently than the tin; from which it differed also in retaining its malleability. (7.) Mercury precipitated from aquafortis, and well edulcorated, being treated with the salt in a glass retort, with a fire raised to the utmost, only 12 grains of mercury sublimed; 28 remaining united with the acid, in a whitish, semi-opaque mass. A solution of this mixed in distilled water, deposited a quantity of a yellowish powder; which, by distillation in a glass retort, was in great part revived into a running mercury. A part also remained dissolved in the clear liquor; for a drop let fall on polished copper instantly whitened it. (8.) Regulus of antimony melted with the vitreous salt, lost eight or nine grains, (about $\frac{1}{5}$); the regulus assumed a fine, brilliant, striated appearance; the scoriæ were somewhat opaque. (9.) Bismuth lost eight grains; the scoriæ were like the preceding, but the bismuth itself suffered little change. (10.) Zinc, mixed with the salt, and distilled in a glass retort, yielded a true phosphorus, which arose in a very moderate heat. The residuum was of a grey colour, a little melted at

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the bottom, in weight not exceeding two drachms; so that two scruples had sublimed. This residuum, urged further in a small Hessian crucible to perfect fusion, emitted an infinity of phosphorine flashes, with a kind of detonation. The matter, grown cold, looked like the scoriæ of melted glass. (11.) White arsenic, mixed with this salt, separated in the fire, greatest part of it subliming, and only as much remaining behind as increased the weight of the salt eight or nine grains. This compound appeared at first transparent; but, on being exposed to the air, became moist, and of an opaque whiteness, much resembling crystalline arsenic. (12.) Cinnabar totally sublimed; suffering no change itself, and occasioning none in the salt. Sulphur did the same. (13.) One part of the salt, mixed with ten of manganese, and melted in a close vessel, gave a semitransparent mass, some parts of which were bluish. The crucible was lined with a fine purple glazing, and the edges of the mass itself appeared of the same colour.

"The vitreous salt dissolved also, in fusion, metallic calces and earths. Chalk, with one-third its weight of the salt, formed a semitransparent vitreous mass: calcined marble, with the same proportion, flowed so thin as to run all through the crucible; gypsum, likewise, ran mostly through the crucible; what remained was semitransparent. Lapis specularis ran entirely through the vessel. Spanish chalk gave a semitransparent mass, which sparkled on breaking; and fine white clay, a similar one. Saxon topaz and flint were changed into beautiful opal coloured masses; the earth of alum into a semitransparent mass, and quicklime into an opaque white one. The mass with flints imbibed moisture from the air; the others not.

"Oil of vitriol, poured upon one fourth its weight of this salt in a retort, raised an effervescence, acquired a brownish colour, and afterwards became turbid and white. On raising the fire, the oil of vitriol distilled, and the matter in the bottom of the retort melted. In the neck was found a little sublimate, which grew moist in the air; as did likewise the remaining salt, which was opaque and whitish. Concentrated spirit of nitre, distilled with this salt in the above proportion, came over unchanged; no sublimate appeared; the residuum looked like glass of borax. The distilled spirit did not act in the least upon gold, even by coction. Strong spirit of sea-salt being distilled in the same manner, no sensible change was made either in the spirit or the salt.

"Equal parts of the vitrified microcosmic salt and salt of tartar being urged with the strongest fire that a glass retort could bear, nothing sensible came over, nor did the mixture appear in thin fusion. Dissolved in water, filtered, and duly evaporated, it afforded, very difficultly, oblong crystals, somewhat alkaline; the quantity of alkali having been more than enough to saturate the acid. A whitish matter remained on the filter, amounting to seven or eight grains, from two drachms of the mixture; this, after being washed and dried, melted before a blow-pipe, as did likewise the crystals.

907 Expels the acids of vitriolated tartar, nitre, and sea-salt.

"This salt seems to extricate, in part, the acids of vitriolated tartar, nitre, and sea-salt. (1.) On distilling a mixture of it with an equal quantity of vitriolated tartar, there came over some ponderous acid drops, which, saturated with fixed alkali, formed a neutral salt greatly resembling the vitriolated tartar. The residuum readily dissolved in water, and difficultly crystallized. (2.) Nitre, treated with the same proportion of the salt, began to emit red vapours. The residuum was of a peach-blossom colour, appeared to have melted less perfectly than the preceding, and dissolved more difficultly in water. The solution deposited a little earthy matter; and, on being slowly evaporated, shot into crystals, which did not deflagrate in the fire. (3.) Sea-salt, distilled in the same manner, manifestly parted with its acid; the residuum was whitish, readily dissolved in water, and afforded some cubical crystals. (4.) Sal ammoniac suffered no change. (5.) Borax, with an equal quantity of vitreous salt, run all through the crucibles.

"Solutions of this salt precipitated the earthy part of lime-water, of solution of alum, of flint dissolved in fixed alkali, and the combination of marine acid with chalk or quicklime. The precipitate from this last liquor is tenacious like glue, and does not dissolve even in boiling water; exposed to a strong fire, it froths prodigiously, and at last melts into a thick scoria.

"Solutions of this salt precipitate also sundry metallic solutions; as butter of antimony, solutions of silver, copper, lead, iron, mercury, and bismuth, in the nitrous acid; and of tin in aqua-regis. The precipitate of iron from spirit of salt is a tenacious mass; that of silver from aquafortis, sometimes a white powder, sometimes tenacious. Copper from aquafortis is sometimes thrown down in form of a white powder, and sometimes in that of a green oil, according to the proportions and diluteness of the liquor. Silver is not precipitated at all by this acid from its solution in vinegar, nor gold from aqua-regis.

"An ounce of the vitreous salt, well mixed with half an ounce of soot, and committed to distillation, yielded a drachm of fine phosphorus. The black residuum, being elixated with boiling water, and the liquor passed through a filter, there remained upon the filter eight scruples of a black matter; and, on evaporating and crystallizing the liquor, about seven drachms were obtained of oblong crystals, which did not deliquate in a moist air, but became powdery in a warm one. These crystals, treated afresh with inflammable matter, yielded no phosphorus. Before a blow-pipe they melted into a transparent globular mass, which on cooling, became turbid and opaque. Dissolved in water, they precipitated solutions of silver, mercury, copper, and of chalk; though they did not act upon the latter so powerfully, nor produce with it a gluey mass, as before they had been deprived of their phosphorine acid."

Mr Wiegleb informs us, that the phosphoric acid exhibits less affinity with calcareous earth, in the moist way, than the vitriolic; though it cannot be separated from the ultimate residuum of the calcareous earth by that acid. It expels, however, all the liquid acids from their basis in the dry way. It precipitates iron from a solution in vitriolic acid, of a perfectly white colour. For the uses of this acid as a flux, see the article *Blow-pipe*.

§ 10. *Of the Acid of Ants.*

2d 907 How procured.

The acid may be obtained from these insects either

by

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by diftillation, or fimple infufion in water. From twenty-four ounces of ants, Neumann obtained eleven ounces and a half of acid as ftrong as good vinegar, by diftillation in balneo mariæ. Of this acid, Mr Margraaf gives the following account in the Berlin Memoirs for 1749.

908 Its properties.

"The acid of ants effervefces with alkaline falts, both fixed and volatile. With volatile alkalies it forms a neutral liquor, which, like that compofed of the fame alkalies and vinegar, yields no concrete falt on diftillation. With fixed alkalies it concretes, upon proper exhalation, into oblong cryftals, which deliquate in the air. The cryftals, or the faturated neutral liquor uncryftallized, on being diftilled with a fire increafed till the retort began to melt, yielded, a liquor fcarce fenfibly acid, and afterwards a fmall quantity of an urinous and partly ammoniacal liquor. The remaining black matter, diffolved in diftilled water, filtered and evaporated, fhot into large cryftals which did not deliquate in the air, though they were in tafte ftrongly alkaline, effervefced with acids, and had all the other properties by which fixed alkalies are diftinguifhed.

"This acid diffolves, with great effervefcence, coral, chalk and quicklime; and concretes with them all into cryftals which do not deliquate in the air.

"It does not precipitate filver, lead, or mercury, from the nitrous acid; nor quicklime from the marine. Hence it appears to have no analogy to the marine or vitriolic acids; the firft of which conftantly precipitates the metallic folutions, and the other the earthy.

"It does not act upon filings of filver; but (like vegetable acids), it totally diffolves, by the affiftance of heat, the calx of filver precipitated from aquafortis by falt of tartar.

"It does not diffolve calces of mercury, (as vegetable acids do); but revives them into running quickfilver.

"It acts very weakly upon filings of copper; but perfectly diffolves copper that has been calcined. The folution yields beautiful compact green cryftals.

"It diffolves iron-filings with violence; the folution duly evaporated, fhoots into cryftals more readily than that made in diftilled vinegar. It fcarcely acts at all upon filings of tin.

"It does not, according to Mr Margraaf, corrode filings of lead; but diffolves, by the affiftance of heat the red calx of lead. The folution cryftallizes into a faccharum faturni. In Mr Ray's philofophical letters, it is faid, that *lead* put into the acid fpirit, or fair water, together with the animals themfelves, makes a good *faccharum faturni*; and that this faccharum, on being diftilled will afford the fame acid fpirit again, which the faccharum faturni made with vinegar will not do, but returns an inflammable oil with water, but nothing that is acid; and faccharum faturni made with fpirit of verdegris doth the fame in this refpect with the fpirit of pifmires.

"It diffolves zinc with vehemence, and fhoots, upon due evaporation, into inelegant cryftals, not at all like thofe produced with diftilled vinegar. On bifmuth, or regulus of antimony, it has little effect, either when calcined or in their metalline ftate.

Acid of amber and its combinations.

§ II. *Of the Acid of* Amber.

The nature of this acid is as yet but little known, and Mr Pott is the only chemift who feems to have examined it with accuracy. We fhall therefore give an abftract of the principal obfervations and experiments he has made on this falt.

909 Mr Pott's experiments.

"Salt of amber requires a large quantity of water for its folution. In the firft cryftallization (being much impregnated with the oil which rifes from the amber along with it), it fhoots into fpongy flakes, in colour refembling brown fugar-candy; the cryftals which fucceed prove darker and darker coloured. On repeating the depuration, the cryftals appear at top of a clear yellow or whitifh colour, in form of long needles or feathers; at bottom, darker, and more irregular, as are likewife the cryftals which fhoot afterwards. The cryftals neither liquefy nor become powdry in the air: rubbed, they emit a pungent fmell like that of radifhes, efpecially if warmed a little; their tafte is acid, not in the leaft corrofive, but with a kind of oily pungency.

"This falt, kept in the heat of boiling water, lofes nothing of its weight, and fuffers no alteration. In a great heat it melts like oil; after which a little oily acid arifes, then oily ftriæ appear in the lower part of the retort, and the falt fublimes into the neck, partly in the form of a dark yellow butter, and partly in that of feathers, a black coaly matter remaining at bottom; fo that, by this procefs, a part of the falt is deftroyed.

"Oil of turpentine has no action on this falt. Highly rectified fpirit of wine gains from it a yellow colour in the cold; and, on the application of heat, diffolves a confiderable quantity, but depofites great part of it on cooling. The falt thus depofited is fomewhat whiter than before, but ftill continues fenfibly yellow. The dulcified fpirit of fal ammoniac diffolves it readily, without effervefcence, into a yellow liqour; if the falt was foul, the folution proves of a red colour; on burning of the vinous fpirit, a neutral liquor remains.

"A folution of falt of amber in water, faturated with a pure alkaline lixivium, yielded, on infpiffation, a faline matter, which would not cryftallize, and which when exficcated by heat, deliquated in the air, leaving a confiderable proportion of an earthy, unctuous matter. Being again gently infpiffated, it left a brownifh falt very foluble, weighing one half more than the falt of amber employed. This falt effervefced with the vitriolic and nitrous acids: the vapour, which exhaled, was not acid, but oily and fulphureous. On repeating the experiment, and fully faturating the alkali with the falt of amber, the neutral falt made no effervefcence with thefe acids. This falt did not perfectly melt before a blow-pipe; continued in the fire for fome time, it effervefced with aquafortis. In diftillation it yielded a bitter, oily, alkalefcent fpirit, much refembling the fpirit of tartar; and towards the end, an empyreumatic oil. The refiduum elixated, yielded the alkaline falt again of a brown colour.

"Salt of amber effervefces ftrongly with volatile alkalies; and, on faturation, forms with them an oily am-

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ammoniacal liquor, which, in diſtillation, totally ariſes in a fluid form, except that a ſmall portion of a penetrating, oily, ſaline matter, concretes towards the end.

910 Effects of the acids of ſal ammoniac and nitre.

"On diſtilling ſalt of amber with an equal quantity of common ſal ammoniac, a marine acid ſpirit came over, of a ſtrong ſmell, and a brown colour: afterwards, a little white ſal ammoniac ſublimed; at length aroſe ſuddenly a large quantity of a fuliginous or bituminous matter, leaving behind a ſmall portion of a like ſhining black ſubſtance. The coaly matter was conſiderably more in quantity than the ſalt of amber employed. On treating it with nitre, red vapours aroſe, and the mixture detonated with violence. A mixture of it with borax, frothed and ſwelled up much more than borax by itſelf; and, on raiſing the fire, yielded only ſome oily drops; the acid being deſtroyed by this ſalt, as by fixed alkalies and quicklime.

911 Purified by the marine acid.

"Spirit of ſea-ſalt, poured upon one-fourth its weight of ſalt of amber, made ſcarce any ſolution in the cold: on the application of heat, nearly the whole coagulated into the conſiſtence of a jelly. In diſtillation, the ſpirit of ſalt aroſe firſt; then almoſt the whole of the ſalt of amber, partly like firm butter, partly like long ſtriated plumous alum, very pure, and of a fine white colour, its oily matter being changed into a coal at the bottom. The ſalt, thus purified, makes no precipitation in the ſolution of ſilver, and conſequently retains nothing of the marine acid; nor does it precipitate ſolution of quicklime made in ſpirit of ſalt, and conſequently contains nothing vitriolic. If any of the mineral acids was contained in this ſalt, it could not here eſcape diſcovery; the oil, which in the rough ſalt is ſuppoſed to conceal the acid, being in this proceſs ſeparated.

912 Effects of ſpirit of nitre on it.

"Aquafortis being poured upon one-fourth its weight of ſalt of amber, extracted a yellowiſh colour from it in the cold, but diſſolved little: on the application of heat, the whole diſſolves into a clear liquor, without any coagulation: if the ſalt is very oily, the ſolution proves red. In diſtillation, the greateſt part ariſes in a liquid form, with only a very ſmall quantity of concrete ſalt. The ſpirit does not act upon gold, but diſſolves ſilver, and quickſilver, as at firſt; a proof that it has received no marine acid from the ſalt of amber.

913 Of oil of vitriol.

"Oil of vitriol being added to twice its weight of ſalt of amber diluted with a little water, a moderate fire elevated an acidulous, liquor, which appeared to proceed from the ſalt of amber; for its making no change in ſolution of fixed ſal ammoniac, ſhowed it not to be vitriolic. On continuing the diſtillation by a ſtronger fire, greateſt part of the ſalt ariſes undeſtroyed, and the oil of vitriol along with it; a black, light, porous earth remaining.

914 Of quickſilver.

"Equal parts of quicklime and ſalt of amber gave over in diſtillation only an acidulous phlegm; the reſiduum, elixated with water, yielded a ſolution of the lime in the acid of amber, reſembling a ſolution of the ſame earth in vegetable acids, precipitable by alkaline ſalts, and by the vitriolic acid. Lime, added to a watery ſolution of ſalt of amber, diſſolves with ſome effervèſcence; after which, the whole coagulates into the conſiſtence of a jelly: this, diluted with water, proves ſimilar to the foregoing ſolution.

Acid of arſenic and its combinations.

915 Effects of ſalt of amber on the metals.

"Solution of ſalt of amber makes no precipitation in ſolution of ſilver or quickſilver. It diſſolves zinc, as all acids do: fixed alkalies precipitate the zinc: the volatile do not; and when a ſufficient quantity of the volatile has been added, the fixed make no precipitation. It acts exceedingly ſlowly and difficultly upon copper; but corrodes calcined copper in a ſhorter time. It ſoon corrodes iron, by coction, into a crocus, and diſſolves a part into a liquid form: the ſolution has little colour; but alkaine ſalts readily diſcover that it holds iron, by rendering it turbid and whitiſh, and throwing down a conſiderable quantity of a greeniſh calx."

§ 12. *Of the acid of* Arsenic.

916 How firſt diſcovered.

Mr Scheele firſt perceived, from ſome experiments on mangaueſe, that arſenic contained phlogiſton: from whence he was led to an analyſis of this ſubſtance, which produced an acid of a very ſingular kind; by uniting of which with phlogiſton in certain proportions, either white arſenic or its regulus may be compoſed at pleaſure.

917 Two ways of decompounding arſenic.

White arſenic may be decompounded in two ways. 1. Put two ounces of it reduced to a fine powder in a glaſs mortar into a retort of the ſame materials; pour upon it ſeven ounces of pure muriatic acid, whoſe ſpecific gravity is to that of water as 10 to 8; and lute on a receiver. The arſenic is quickly diſſolved in a boiling heat, which muſt be brought on as quickly as poſſible. After the ſolution is accompliſhed, while the liquor is ſtill warm, three ounces and a half of nitrous acid, of the ſame ſpecific gravity with the muriatic above-mentioned, is to be added, and the liquid which had already gone over into the receiver poured back. The receiver is then to be put on again, but not luted; the mixture ſoon begins to effervèſce, and red vapours go over into the receiver. The diſtillation is to be continued till theſe vapours ceaſe; when an ounce of finely powdered arſenic is again to be added, the receiver applied as before, and a gentle ebullition continued till the ſecond quantity of arſenic be diſſolved. An ounce and an half of nitrous acid is then to be added, and the mixture diſtilled to dryneſs, increaſing the fire towards the end, ſo as to make the retort red hot. The acid which comes over into the receiver may ſerve again ſeveral times. The white maſs which remains in the retort is the dry acid of arſenic. It may be reduced to a liquid form by pouring upon it, in coarſe powder, twice its weight of diſtilled water, and boiling for a few minutes, pouring back the liquor which comes over, and afterwards filtering the ſolution through blotting paper, which has been previouſly waſhed in hot water.

918 By means of nitrous acid.

In this proceſs the nitrous acid attacks the phlogiſton of the arſenic, is volatilized in conſequence of its union with it, and leaves the more fixed but leſs powerful acid of arſenic behind. The nitrous acid would alone be ſufficient for this purpoſe, could it accurately come into contact with the particles of arſenic; but this cannot be done without ſolution, and the nitrous acid is capable of diſſolving arſenic only in pro-

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proportion to the water it contains. Too great a quantity would therefore be required were this acid to be used by itself; but by the use of muriatic acid for the solution, a smaller quantity of spirit of nitre is admitted to intimate contact with all the arsenical particles, and has an opportunity of depriving them of their phlogiston. Aqua-regia might be poured upon the arsenic at once; but the greatest effervescence it excites would throw the mineral up to the top in such a manner that the menstruum could not act upon it. By the operation of dephlogistication, arsenic loses a fifth part, which is supposed to be pure phlogiston.

919 By dephlogisticated spirit of salt.

The other method of decomposing arsenic is, by means of the dephlogisticated spirit of salt. For this purpose, take one part of powdered manganese, and mix it with three of the muriatic acid above-mentioned. Put it into a retort, of which it may fill one-fourth; a receiver containing one-fourth of powdered arsenic, with one-eighth of distilled water, is to be luted on, and the retort put into a sand-bath. The dephlogisticated muriatic acid, going over into the receiver, is instantly absorbed by the arsenic; which some hours afterwards will be dissolved, and two different liquid strata, which cannot be mixed together, will be perceived in the receiver. This solution is now to be put into a clean glass retort, and distilled to dryness; increasing the fire at last to such a degree as to make the whole red hot: and in this process also two different liquids pass over into the receiver which do not unite together.

Here the manganese attracts the phlogiston of the muriatic acid; and as this dephlogisticated acid has a very strong attraction for phlogiston, it deprives the arsenic of its phlogiston, and thus recomposes the ordinary phlogisticated muriatic acid. This portion of recomposed acid dissolves part of the arsenic, forming with it what is called *butter of arsenic*. The other part of the arsenic which has been decomposed, dissolves in the water, and forms a liquid specifically lighter than the butter, and therefore swims above it. On rectifying the two liquids, the undecomposed portion of the arsenic arises along with the muriatic acid, and goes over into the receiver in form of an heavy oil, while the acid of arsenic remains behind in the retort. The acid obtained in this way is precisely the same with the former, and one would hardly believe that it is an acid, because it has no acid taste; but after some days it grows moist in the air, and at last deliquates, assuming the appearance of oil of vitriol. As the deliquescence, however, is very slow, it is proper to dissolve it in a certain quantity of water, when a small quantity of white powder remains undissolved, after preparing it by the first process, which is siliceous earth derived from the retort. This ought to be carefully separated from the acid by filtration; and in order to prevent the glue of the blotting-paper from mixing with the acid, it was directed to wash the filter with hot water previous to the operation.

920 Acid of arsenic equally poisonous with the white arsenic itself.

The first experiment M. Scheele tried on this acid after he had obtained it, was to discover if it was as noxious to animals as when combined with phlogiston. Having mixed a little with honey, the flies that eat of it died in an hour; and eight grains reduced a cat to the point of death in two hours. Some milk, however, being then given to the animal, it vomited violently, and ran away.

921 Easily resumes its phlogiston.

2. An ounce of dry acid of arsenic, heated in a small phial to near the point of ignition, melts into a clear liquid, which congeals when cold; but if the heat be increased till the vessel begins to melt, the acid begins to boil, resumes its phlogiston, and arsenic sublimes in greater quantity as the heat is longer continued. After subjecting the acid to this violent heat in a retort for an hour, the vessel melted, and the acid had risen up as high as the neck.

3. In a crucible the arsenic attracts phlogiston in greater quantity, and is entirely dissipated in arsenical vapours; a little clear and difficultly fusible glass, consisting of clay and the acid of arsenic, remaining in the crucible.

922 Takes fire and sublimes charcoal.

3. With powder of charcoal the arsenical acid undergoes no change; but if the mixture be put into a retort, the moisture all driven off, a receiver then luted on, and the heat increased till the bottom of the retort becomes red hot, the whole mass takes fire with violence; all the acid is reduced, and sublimed into the neck of the retort; a shining regulus is obtained, mixed with a little arsenic and charcoal dust. A few drops of water are found in the receiver, but they do not contain a particle of acid.

923 Appearance with oil of turpentine, &c.

4. The arsenical acid, after some days digestion with oil of turpentine, unctuous oil, and sugar, becomes black and thick. If some muriatic acid be distilled from this, a little nitrous acid added, and the distillation repeated, some acid of arsenic is left behind. Spirit of wine undergoes no change either by digestion or distillation with arsenical acid.

924 With sulphur.

5. Six parts of acid digested with one of sulphur suffer no change; but when the mixture is evaporated to dryness, and then subjected to distillation in a glass retort, the two unite with great violence at that degree of heat in which sulphur melts; and the whole mass rises almost in the same instant, in form of a red sublimate; a little sulphureous acid in the mean time going over into the receiver.

925 Combined with vegetable fixed alkali.

6. Acid of arsenic, saturated with vegetable fixed alkali, forms a deliquescent salt which does not crystallize, but turns syrup of a violet green, though it produces no change on the tincture of lacmus. On the addition of a little more acid, however, when it reddens lacmus, but makes no alteration on the syrup of violets, the liquor will afford fine crystals like Mr Macquer's neutral salt of arsenic. On keeping this salt for an hour in fusion in a crucible covered with another luted upon it, the inside of the vessel was found covered with a white glazing, and a salt remained, which was still the same arsenicated salt with excess of acid.

926 This salt decomposed by charcoal.

7. On distilling this salt in a retort with an eighth part of charcoal-dust, it began to boil very violently as soon as the retort became red-hot, and a very fine regulus of arsenic sublimed. The black residuum contained the alkali entirely separated from the arsenical acid.

927 Combined with mineral alkali.

8. With mineral alkali the acid of arsenic forms crystals when perfectly neutralized, but not if added to excess. In that case, the mass becomes deliquescent like the former when neutral.

928 With volatile alkali.

9. With volatile alkali a salt much resembling the two

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two former is produced. It does not change lacmus, but turns the ſyrup of violets green. A gentle heat drives off part of its volatile alkali, and leaves the remainder ſuperſaturated with acid; in which caſe it ſhoots into long radiated and deliqueſcent cryſtals. Theſe, urged by a ſtronger heat, part with the whole of their alkali, which is partly decompoſed; ſome arſenic is formed by the union of the phlogiſton of the alkali with part of the arſenical acid; the remainder of which aſſumes a milky colour, and lies in the bottom of the retort.

929. Expels the acid of vitriolated tartar by dry diſtillation.

10. Acid of arſenic diſtilled with vitriolated tartar expels the vitriolic acid in a violent heat, which comes over in a concentrated but ſulphureous ſtate, leaving the arſenical ſalt formed of the acid and alkali united. With Glauber's ſalt the vitriolic acid alſo riſes, and with leſs heat than when vitriolated tartar is made uſe of.

930 Acid of nitre;

11. One part of nitre diſtilled with three of acid of arſenic, yielded a ſpirit of nitre, together with the neutral arſenical ſalt already mentioned.

931 Of common ſalt.

12. One part of common ſalt with three of arſenical acid, yielded ſome ſmoking part of ſalt. The reſiduum diſſolved in water gave cryſtals of common ſalt, and a thick magmum, which would not cryſtallize till the ſuperfluous arſenical acid was taken away by adding powdered chalk, when it yielded cryſtals ſimilar to thoſe produced by the acid and pure alkali.

932 Phenomena with ſal ammoniac.

13. With ſal ammoniac the product was firſt fuming muriatic acid, then volatile alkali in a liquid ſtate, after that arſenic, and laſtly part of the arſenical acid remained in the retort.

633 Decompoſes ſpathum ponderoſum and gypſum.

14. Spathum ponderoſum, and gypſum, both parted with their acids, which were become ſulphureous. The former did not yield its acid till the retort began to melt.

634 Cannot expel the fluor acid.

15. One part of fluor mineral was mixed with four of acid of arſenic, and diſtilled into a receiver having a little water in it. When the retort grew red-hot, firſt a yellow and then a red ſubſtance ſublimed. Some ſulphureous acid, but none of the acid of fluor, went over. A grey-coloured reſiduum was left in the retort; which being divided into two parts, one was mixed with charcoal-powder and diſtilled with a ſtrong fire, without the production of either arſenic or regulus; the other was mixed with four parts of acid of arſenic, and ſubjected to a ſecond diſtillation. When the maſs grew dry, a little yellow ſal ammoniac was ſublimed, and the water was covered with a cruſt of ſiliceous earth, as in the uſual diſtillations of that mineral.

635 Precipitates lime water

16. Arſenical acid precipitates lime-water, by uniting with the calcareous earth diſſolved in it. By the addition of more acid, the precipitate is diſſolved, and the liquor yields ſmall cryſtals, which let fall a ſelenite on the addition of vitriolic acid.

636 Phenomena with chalk.

17. On the addition of powdered chalk to arſenical acid diluted with water, the earth is at firſt diſſolved, but by adding more chalk the whole is coagulated into ſmall cryſtals.

937 With magneſia.

18. Magneſia diſſolves in the arſenical acid, and the ſolution coagulates when it comes to the point of ſaturation. On diſſolving the coagulum in a larger quantity of water, it becomes gelatinous by evaporation; and if the jelly be lixiviated with water, filtered, and evaporated, a viſcid maſs remains, which refuſes to cryſtallize.

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938 With earth of alum.

19. Earth of alum precipitated by alkali of tartar, is eaſily ſoluble in arſenical acid, and coagulates as ſoon as it arrives at the point of ſaturation. Evaporated to dryneſs, mixed with ſome charcoal powder, and then ſubjected to ſtrong diſtillation, a little yellow ſublimate ariſes into the neck of the retort, as likewiſe ſome ſhining regulus, while a volatile ſulphureous acid paſſes over into the receiver. The reſiduum diſſolves with difficulty in the vitriolic acid, though ſome cryſtals of alum will form in the ſpace of two months.

939 With white clay.

20. Four parts of arſenical acid mixed with one of powdered white clay, did not diſſolve any part by digeſtion for a fortnight. By diſtillation in a retort till the veſſel began to melt, it was converted into a thick flux, and a little arſenic ſublimed. By mixing the reſiduum with a little powdered charcoal, a ſhining regulus was ſublimed.

940 With terra ponderoſa.

21. Terra ponderoſa diſſolves readily in the acid of arſenic, but precipitates again as ſoon as it has attained the point of ſaturation. The ſolution is precipitated by acid of vitriol, and forms regenerated ponderous ſpar.

941 With gold.

22. Gold is not acted upon by acid of arſenic, either by digeſtion or otherwiſe; nor is its ſolution precipitated, though the retorts uſed in the operation were ſtained with red and yellow ſpots, which could not be taken off; nor is its action increaſed by mixture with muriatic or with nitrous acid.

942 Platina.

23. Pure platina is not acted upon. Its ſolution is not precipitated by the pure arſenical acid, but readily by the arſenical ſalts. The precipitate is yellow, and diſſolves in a large quantity of water, but contains no mark of arſenical acid. Addition of muriatic or of nitrous acid makes no change in its effects.

943 Silver.

24. Pure ſilver is not acted upon by the arſenical acid in digeſtion. On augmenting the fire till the acid melted, and keeping up this degree of heat for half an hour, the metal diſſolved, and on breaking the retort, a colourleſs glaſſy maſs, nearly tranſparent, was found in it; the retort being covered with a flame-coloured glazing, which could not be ſeparated from it. By a great degree of heat the ſilver was reduced without addition. Solution of ſilver is precipitated by pure acid of arſenic, but more effectually by the neutral arſenical ſalts: the precipitate is of a brown colour, and by digeſtion in muriatic acid is changed into lunea cornea; it is alſo ſoluble in ſpirit of ſal ammoniac prepared with quicklime. The action of the arſenical acid upon ſilver is conſiderably increaſed by mixing it with ſpirit of ſea-ſalt; the former attacking the phlogiſton of the metal, while the latter attacks its earthy baſis.

944 Quickſilver.

25. Quickſilver is not acted upon by digeſtion with arſenical acid. On putting the mixture into a retort, diſtilling to dryneſs, and then increaſing the fire, the maſs becomes yellow, quickſilver riſes into the neck of the retort, with a little arſenic. and ſome yellow ſublimate; but though the fire was augmented till the retort began to melt, the maſs could not be fuſed. Three drachms and an half of quickſilver were obtained out of ſix employed in the experiment; the arſenical acid, therefore, contained two and an half. The maſs was ſomewhat yellow: it diſſolved very readily in muriatic acid, but ſcarcely at all in the nitrous or vitriolic; on evaporation to dryneſs and diſtillation, ſome corroſive ſublimate

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sublimate rose into the neck of the retort; the residuum, melted in a very strong fire, proved to be acid arsenic. Another portion of the mass, distilled with two parts of common salt, yielded corrosive sublimate.

945 With corrosive sublimate.

26. Acid of arsenic distilled with corrosive sublimate undergoes no change; but by sublimation with mercurius dulcis, a corrosive sublimate is obtained. Some have asserted, that by subliming arsenic with corrosive sublimate, a butter of arsenic is obtained; but Mr Scheele informs us that this is a mistake; and that by distilling this mixture, he constantly obtained corrosive sublimate at first, and arsenic afterwards. With regulus of arsenic, however, a smoking butter of arsenic, mercurius dulcis, and some quicksilver, are obtained. The same thing happens with a mixture of orpiment and corrosive sublimate.

946 Butter of arsenic is not obtained by this process.

947 With copper.

27. Arsenical acid dissolves copper by a digesting heat. The solution is of a green colour: a quantity of light blue powder is deposited, and attaches itself to the copper. This powder consists of the acid of arsenic and calcined copper. On mixing two parts of dry acid of arsenic, in fine powder, with one of filings of copper, and distilling the mixture, some arsenic rose into the neck, and the mass melted and turned blue. On boiling it with water, the solution was similar to one made directly from acid of arsenic and copper. A little copper remained in the bottom of the retort, which was tinged with brown, red, and yellow spots, insoluble in any menstruum. The solutions of this metal are not precipitated by arsenical acid, but the acetous solution is. Neutral arsenical salts throw down a blue precipitate, which by exposure to a strong fire, turns brown and covers the inside of the containing vessel with a yellow enamel. On mixing the scoria in a fine powder with a little lampblack, some fine regulus of arsenic sublimed, and the copper in the residuum was reduced.

948 With iron.

28. With iron the acid of arsenic forms a gelatinous solution, which by exposure to the air grows so thick that in two hours time it will not flow out at the mouth of a phial. With alkali of tartar a whitish green powder is thrown down; which being edulcorated and distilled in a glass retort, yields some arsenic, and leaves a red ochre behind. On distilling four parts of arsenical acid with one of iron filings, the mass effervesced strongly towards the end; and when it became dry, took fire in the retort upon increasing the heat, when both arsenic and regulus of arsenic were sublimed. The residuum was black, friable, and contained but little acid of arsenic; the retort was covered with yellowish brown spots. Solutions of iron in mineral acids are not precipitated by acid of arsenic, but the acetous solution lets fall a dark brown powder. All the solutions are precipitated by the arsenical neutral salts, the precipitates by a strong fire, converted into black scoriæ; which mixed with powdered charcoal, and calcined, yield copious vapours of arsenic, and are afterwards attracted by the magnet.

949 With lead.

29. Lead digested with arsenical acid turns black at first, but in a few days is surrrounded with a light greyish powder, containing some arsenic which may be separated by sublimation. On distilling one part of shavings of lead with two of dry acid of arsenic, the lead was dissolved, the mass flowed clear, and a little arsenic rose into the neck of the retort. A milky glass was found in the bottom, which by boiling in distilled water, let fall a quantity of white powder, the superfluous acid being dissolved in the water; the edulcorated powder yielded regulus of arsenic by distillation with charcoal. Solutions of lead in nitrous and muriatic acids are precipitated by arsenical acid.

950 With tin.

30. Tin digested with acid of arsenic becomes first black, then is covered with a white powder, and afterwards becomes gelatinous. One part of tin filings distilled with two of acid of arsenic, took fire as soon as the retort became red-hot, and immediately after both arsenic and a little regulus were sublimed. The tin was dissolved into a limpid liquor, which became milky when cold.—By washing in water, a quantity of white powder was separated, insoluble in any acid, and containing very little of that of arsenic.

251 With zinc.

31. Arsenical acid dissolves zinc with effervescence. The metal grows black, and the transparency of the acid is destroyed by a quantity of black powder. This powder edulcorated, dried, and put on an iron plate heated nearly red-hot, emits a blue flame and white arsenical smoke in the dark, leaving behind a white powder; thus manifesting itself to be mostly regulus of arsenic. One part of filings of zinc distilled with two of acid of arsenic, took fire in the retort with a very bright flame, and burst the vessel with an explosion. Some regulus of arsenic and flowers of zinc were found in the neck.

952 With bismuth.

32. Bismuth digested with acid of arsenic is covered with a white powder; water precipitates the solution, and the precipitate consists of calcined bismuth and acid of arsenic. On distilling one part of the bismuth with three of arsenical acid, the mass melted, the metal was calcined, but remained undissolved in the bottom of the vessel; a little arsenic rose into the neck; and after the retort became cool, water was poured on the residuum, which dissolved the acid, but the calx of bismuth remained unchanged. Solution of this semimetal in the acid of nitre was precipitated by arsenical acid. This precipitate, as well as the calx, are very difficult of fusion, but on adding a little powdered charcoal, the mixture instantly melts, the arsenic goes off in vapours, and the bismuth is reduced.

953 Regulus of antimony.

33. With regulus of antimony a quantity of white powder is produced by digestion, and the clear solution is likewise precipitated by dropping it into pure water. This powder is soluble only by muriatic acid, and may be precipitated again by the addition of water. One part of regulus of antimony distilled with three parts of arsenical acid, took fire as soon as the mass melted, and regulus of arsenic with a red matter were sublimed; a little volatile sulphureous acid came over into the receiver. On boiling the residuum in water, the acid was dissolved, a white shining powder remained behind, which on being mixed with charcoal powder and distilled, an ebullition took place, some regulus of arsenic rose into the neck of the retort, and the antimony was reduced. Butter of antimony was not precipitated by the pure acid, but very readily by the arsenical salts. Acetous and tartareous solutions of glass of antimony are preciptated by arsenical acid

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954 With cobalt.

34. Cobalt is partially dissolved, and the solution assumes a rose-colour; on putting the whole mass into a retort, distilling off the liquid, and then augmenting the fire, the mass melted, and a little arsenic was sublimed. The residuum when cold had a semi-transparent violet colour. On pouring water upon it, and putting it on hot sand, the acid was dissolved, the violet colour disappeared, and the solution assumed a dark-red colour. The bottom of the retort had a blue tinge, which could not be taken off. Solutions of cobalt in mineral acids are readily precipitated by the arsenical neutral salts. The precipitate is of a rose-colour, but melts with difficulty into a dark blue scoria.

955 With nickel.

35. Nickel, with acid of arsenic, assumes a dark green colour, and lets fall a green powder containing arsenic in substance, which may be separated from it by a gentle heat. One part of nickel distilled with two of dry arsenical acid, melted with some appearance of inflammation, yielding some arsenic at the same time. The mass was yellow, with a number of grey elevated streaks upon it, which appeared like vegetation, and were formed during the distillation. On boiling the yellow mass in water, the acid was dissolved, leaving a yellow powder behind; which, when treated with charcoal-powder, yielded regulus of arsenic, but was not reduced itself. The solutions of nickel in acids are not precipitated by arsenical acid, not even that in vinegar, but the neutral arsenical salts throw down a whitish green powder.

956 With manganese.

36. Manganese in its natural state is dissolved only in small part; but when phlogisticated it dissolves readily and totally; though, whenever the acid arrives at the point of saturation, the solution coagulates into small crystals.

957 With regulus of arsenic.

37. Regulus of arsenic digested with its own acid soon becomes covered with a white powder, which is arsenic in substance. On distilling one part of the regulus with two of the acid, the former sublimed and the latter melted. If small pieces of regulus of arsenic be gradually added to the acid of arsenic in fusion, an inflammation takes place, and arsenic is sublimed.

2d 957 Strange phenomenon of arsenic with terra foliata tartari.

On distilling a mixture of equal parts of terra foliata tartari and arsenic, a limpid liquor like water first came over, smelling strongly of garlic; on changing the receiver, a liquor of a brownish red colour was collected, which filled the receiver with a thick cloud, emitting an intolerable smell of arsenic. On pouring this upon a filter, hardly a few drops had passed when a very thick stinking smoke suddenly arose as high as the cieling of the room; an ebullition ensued towards the edge of the filtering-paper, and a fine rose-coloured flame broke out, that lasted for some moments.

§ 13. *Of the Acid of* Molybdæna.

958 How to reduce molybdæna to powder.

We owe this, as well as the succeeding acids to the industry of the late Mr Scheele. The substance from which he extracted it is named by Cronstedt *molybdæna membranacea nitens*.—As this substance is of a flaky nature, and incapable of pulverization by itself, our author mixed some pieces of vitriolated tartar along with it in a glass mortar; by the attrition of which it was at last reduced to a fine powder, and which was afterwards freed from the vitriolated tartar by washing with hot water. He then treated this powder with all the known acids, but found none of them to have any effect upon it excepting those of arsenic and nitre.

Acid of molybdæna and its combinations.

959 Effects of the acid of arsenic upon it.

No sensible effect was perceived from the acid of arsenic until the water was evaporated; after which, by increasing the fire, a little yellow orpiment was sublimed in the neck of the retort, and some sulphureous acid passed over into the receiver.

960 Violent action of concentrated nitrous acid upon this substance.

On pouring two parts of concentrated nitrous acid upon one part of powdered molybdæna, the mixture was scarce warm in the retort, when it passed altogether into the recipient with great heat, and in the form of dark red vapours. Had the quantity been larger, he had no doubt that it would have taken fire; for which reason the experiment was repeated with diluted nitrous acid. Six ounces of diluted nitrous acid being poured on an ounce and a half of powdered molybdæna, no effect was perceptible till the liquor began to boil; after which a great number of red elastic vapours began to appear, and the mixture swelled considerably. The distillation being continued to dryness, the residuum appeared of a grey colour; the same quantity of nitrous acid was poured on, and the process repeated, when the residuum was whiter; and on still repeating the operation a fourth and fifth time, the remaining powder became at last as white as chalk. This residuum, after being edulcorated with hot water, was quite tasteless and insipid when dry. The limpid liquor which ran from it being evaporated to half an ounce, first assumed a fine blue colour, and then grew thick. On being examined, it was found to contain some iron, and was otherwise chiefly acid of vitriol. The colour disappeared on diluting the acid with water.

961 Acid of molybdæna obtained by fire alone.

The white powder just mentioned is the true acid of molybdæna, and may be obtained by the help of fire alone. A small piece of molybdæna exposed on a silver plate to the blow-pipe, makes a beautiful appearance, when the white vapours attach themselves to the plate in the form of small shining scales, in the direction of the flame. This white sublimate becomes blue whenever it is in contact with the blue flame; but changes to white whenever the point of the flame is directed against it. An ounce of powdered molybdæna was mixed with four ounces of purified nitre, and detonated in a crucible heated thoroughly red hot. The mass thus obtained was of a reddish colour. On dissolving it in water, the solution was clear and colourless. A small quantity of red powder fell to the bottom of the vessel; which, when dry, weighed 11 grains, and showed itself to be an iron ochre. By evaporation vitriolated tartar and nitre were obtained; but a good deal of lixivium remained, which refused to crystallize, though no mark of superfluous alkali remained. It was then mixed with some water, to which diluted acid of vitriol was added, until no more precipitate fell. The white powder which precipitated weighed three drachms; but if too much acid be added, the precipitate will be redissolved, and the water itself retains a part of it in solution. A precipitate is likewise obtained by means of nitrous or muriatic acid.

962 Its chemical properties.

The precipitate thus obtained, like those which result from the two former processes, is the true acid of molybdæna, and has the following chemical properties.

1. The

Acid of molybdæna and its combinations.

1. The ſolution reddens lacmus, coagulates a ſolution of ſoap, and precipitates hepar ſulphuris. 2. If this ſolution be boiled with the filings of any of the imperfect metals, it aſſumes a bluiſh colour. 3. By the addition of a little alkali of tartar, the earth becomes ſoluble in greater quantity in water; and after evaporation ſhoots into ſmall confuſed cryſtals. 4. Under the blow-pipe this earth is ſoon abſorbed by charcoal; but when placed on a ſilver plate it melts, and evaporates with the ſame phenomena as molybdæna itſelf. 5. By the addition of alkali, the earth is deprived of its property of being volatilized in the fire. 6. The ſolution, whilſt hot, ſhows its acid power more evidently than when cold, and tinges lacmus of a deeper colour. It effervesces with chalk, with magneſia, and with earth of alum; with all of which it forms ſalts very difficult of ſolution in water. 7. It precipitates, from the nitrous acid, ſilver, quickſilver, and lead, as alſo lead diſſolved in marine acid. Theſe precipitates are reduced on burning charcoal, and the melted metal runs into the pores. Corroſive ſublimate is not precipitated; neither are the ſolutions of the other metals. 8. Terra ponderoſa is alſo precipitated from the nitrous and marine acids; and the precipitate is ſoluble in a large quantity of cold water. None of the ſolutions of the other earths are precipitated. 9. Fixed air is alſo expelled by this acid from the fixed and volatile alkalies, and forms with them neutral ſalts which precipitate all other metallic ſolutions. Gold, corroſive ſublimate, zinc, and manganeſe, are precipitated in form of a white powder; iron and tin, from their ſolution in marine acid, of a brown colour; cobalt of a roſe colour; copper of a blue; the ſolutions of alum and quicklime, white; and if the ammoniacal ſalt formed by the earth of molybdæna and volatile alkali be diſtilled, the earth parts with its alkali in a gentle heat, and remains in the retort in form of a grey powder. 10. Concentrated vitriolic acid diſſolves a great quantity of this earth by means of heat. The ſolution acquires a fine blue colour; which, however, diſappears on being heated, or by diluting the acid with water. In a ſtronger heat the acid flies off, leaving the earth unaltered behind. This ſolution becomes thick on cooling. 11. The nitrous acid has no effect upon the earth of molybdæna. 12. Boiled with the muriatic acid it diſſolves in conſiderable quantity; and, on diſtilling the mixture to dryneſs, a dark-blue reſiduum remains. On increaſing the heat, white flowers ariſe, with a little blue ſublimate, and a ſmoking muriatic acid is found in the receiver. The reſiduum is of a grey colour. Theſe flowers are only the earth of molybdæna volatilized by means of the muriatic acid, and therefore manifeſts the ſame properties. 13. If one part of this earth be diſtilled with two parts of vitriolated tartar, a little vitriolic acid paſſes over, at leaſt when the heat is very ſtrong; and the remaining earth is more ſoluble in water than before. 14. With two parts of nitre it expels, by means of diſtillation, a ſtrong nitrous acid; the reſiduum diſſolved in water is a neutral ſalt which precipitates all metallic ſolutions, and is ſimilar to that formed by a direct union of the acid and fixed alkali. 15. Diſtilled with two parts of pure common ſalt, the acid is expelled in a ſmoking ſtate, and white, yellow, and violet-coloured flowers ariſe, which become moiſt in the air, and when ſprinkled on metals give them a blue colour. Theſe flowers, as has been already remarked, are only the acid of molybdæna volatilized by that of ſea-ſalt.

Acid of molybdæna and its combinations.

963 Is capable of uniting with phlogiſton.

The blue colour acquired by this earth on the contact of flame, alſo in the moiſt way in ſome caſes, ſhows that it is capable of contracting an union with the phlogiſton. To reduce this to certainty, Mr Scheele diſſolved ſome of the earth of molybdæna in boiling water, with the addition of a little alkali. Into this ſolution he poured ſome drops of muriatic acid, and divided it into ſeveral parts, into each of which he put filings of ſeveral metals. The ſolutions ſoon acquired a bluiſh colour, which grew deeper and deeper; and in an hour's time, during which the bottle was now and then ſhaken, the liquor aſſumed a fine dark blue. That this colour depends on phlogiſton, he infers from the following circumſtances: 1. If, inſtead of the metals themſelves, you take their calces, no blue colour is produced. 2. If there be dropped into the blue ſolution a few drops of acid of nitre, and the ſolution be then put into a warm place, the colour diſappears. It is therefore no matter of ſurpriſe, that both ſilver and quickſilver ſhould be attacked, ſince a double elective attraction takes place; the muriatic acid uniting with the metallic calx, and the earth of molybdæna with the phlogiſton of the metals. Gold, however, is not attacked in this way. 3. Too great a quantity of muriatic acid produces not a blue but a yellowiſh colour, which at laſt turns brown if the mixture be digeſted; but on adding this ſolution to a ſolution of the earth of molybdæna, a blue colour as uſual is produced. 4. Lixivium ſanguinis, in which the acid prevails, throws down the earth of a brown colour, and the infuſion of galls of a dark brown.

964 Shows no ſign of containing any metal.

The acid of molybdæna, treated with various fluxes, and with charcoal, ſhows no ſigns of containing any metallic matter. Moiſtened with oil-olive, and committed to diſtillation in a ſtrong fire, it did not ſublime, but remained in the retort in the form of a black powder; which, on being calcined in a crucible, ſublimed in white flowers as uſual. On inverting another crucible into the former, and luting the juncture, the earth remained unchanged and of a black colour, without any ſign of fuſion. This black powder did not diſſolve in boiling water, nor even with alkali, which on other occaſions ſo readily diſſolves it; but when mixed with a triple quantity of ſalt of tartar, a great effervescence enſued; the produce was a neutral ſalt reſembling that formed by the direct union of the acid and alkali.

965 Properties of the acid obtained by nitre.

The earth of molybdæna, procured by nitre, requires much leſs water for its ſolution; it does not expel the acid from vitriolated tartar; is more eaſily fuſed, and does not ſublime in an open crucible. When fuſed with charcoal-powder, it affords a ſolution with water, containing a neutral ſalt, which precipitates all others. The reaſon of theſe differences is, that it contains a portion of alkali, though it be ever ſo frequently purified by ſolution and cryſtallization. That this is the caſe we know from the following experiments: 1. If to a ſolution of the nitrous earth of molybdæna we add ſome nitrous acid, the latter attacks the alkali, and the greateſt part of the diſſolved earth is precipitated. This, however, does not happen, except by long boiling. 2. The neutral ſalt obtained by fuſion proves the ſame. This neutral ſalt is produced in the following manner. The earth which contains

Acid of molybdæna and its combinations.

tains only a small quantity of alkali operates as an acid, as appears from its changing the colour of lacmus to red; but the alkali prevents as much earth from entering into it as is necessary to its saturation with phlogiston; for the acid of molybdæna has a greater attraction for alkali than for phlogiston. The charcoal which remains after lixiviating the compound of acid of molybdæna and charcoal, yields vapours in an open crucible, and gives a sublimate containing the phlogisticated earth of manganese. This alkali fixes the earth in the open air; and hence we see also the reason why this earth does not expel the acid from vitriolated tartar; for its attraction for the alkali must diminish in proportion as it comes nearer the point of saturation; and as the pure earth contains no alkali, it attracts a little from the vitriolated tartar; and consequently there can appear but a slight vestige of vitriolic acid. This small quantity of acid likewise occasions its more easy solubility in water.

966 Molybdæna recomposed by uniting its acid with sulphur.

The pure acid of molybdæna recomposes that substance by being combined with sulphur. Mr Scheele having mixed some very fine powder of this earth with three parts of sulphur, and committed the mixture to distillation in a glass retort, the receiver was filled with the superfluous sulphureous vapours, which had also the fetid smell of volatile spirit of sulphur. In the retort a black powder remained, which on every chemical trial was found to be a true molybdæna; so that there is now no doubt of this substance being composed of a particular kind of acid united to sulphur.

§ 14. *Of the Acid of* Lapis Ponderosus, Tungsten, *or* Wolfram.

967 This substance considered as a metallic earth by Mr Bergman.

This substance has been analysed both by Mr Scheele and Mr Bergman, though the former has the merit of discovering the acid contained in it; which the latter considers, as well as the earth of molybdæna, not as truly acid, but as metallic earths. Mr Scheele's experiments for analysing this substance were as follow:

968 Scheele's method of analysing it.

1. On one part of finely powdered tungsten were poured two parts of concentrated acid of vitriol. By distillation the acid passed over unchanged; the residuum, which was of a bluish colour, after being boiled for a short time, and the liquor filtered off, deposited some vitriolated lime or gypsum by standing. 2. Twelve scruples of common nitrous acid, or pure aquafortis, being poured on two of finely powdered tungsten, no effervescence ensued; but on exposing the mixture to a strong digesting heat, it assumed a citron yellow colour. The acid was then poured off into another phial, and the yellow powder edulcorated with water. 3. On this yellow powder eight scruples of caustic volatile alkali were poured, and the phial exposed to heat; on which the yellow colour instantly vanished, and the powder became white. This solution was in like manner put into a separate phial, and the powder edulcorated; and as the matter was sensibly diminished by these operations, they were alternately repeated, till at length the whole was dissolved, excepting three grains, which seemed to be siliceous earth. The same effects ensued on treating this substance with muriatic acid, only the solution was of a deeper yellow colour. 4. The solutions made in the foregoing manner with nitrous acid being all mixed together, some drops of phlogisticated alkali were added; by which about three grains of Prussian blue were precipitated. 5. The mixture was then saturated with caustic volatile alkali; but as no precipitate appeared, a solution of fixed alkali was added, which threw down two scruples and five grains of white earth of a mild calcareous kind. On adding some nitrous acid to the extracts made by volatile alkali, a white powder was precipitated, which, on edulcoration, proved to be the true acid of tungsten.

Acid of lapis ponderosus and its combinations.

969 Effects of heat upon it.

On treating tungsten with a strong heat in the dry way, the following appearances took place: 1. One part of tungsten mixed with four of alkali of tartar was melted in an iron crucible, and then poured out on an iron plate. Twelve times its weight of boiling water being then poured upon it, a white powder subsided to the bottom, which dissolved in a great measure in nitrous acid. 2. The undissolved part of the powder was tried; and being again mixed with four parts of alkali, was melted as before: and the mass being also dissolved in water, and nitrous acid poured on the residuum, only a very small portion of grey powder was left undissolved. 3. The ley being saturated with nitrous acid, grew thick by the precipitation of a white powder; which was afterwards washed with cold water and dried, and then proved to be the same acid of tungsten with that already described. The solution in nitrous acid precipitated with fixed alkali gave a white precipitate, which was found to be calcareous earth.

970 Its chemical properties.

The properties of the acid of tungsten are, 1. Under the blow-pipe it became first of a reddish yellow colour, then brown, and at last black. It neither smoked nor gave any signs of fusion. 2. With borax it produced a blue, and with microcosmic salt, a sea-green glass. 3. Boiled with a small portion of the nitrous or marine acids, the powder becomes yellow, and with the acid of vitriol bluish. 4. On saturating a solution of the acid with fixed alkali, a neutral salt in very small crystals is obtained. 5. With volatile alkali this acid forms an ammoniacal salt, shaped like the points of small pins. On distillation the alkali separates in a caustic state, the acid remaining behind in the retort in form of a dry yellow powder. On mixture with a solution of lime in spirit of nitre, a double elective attraction takes place, the acid of tungsten uniting itself with the lime, and that of nitre with the volatile alkali. 6. With magnesia the acid of tungsten forms a salt very difficult of solution. 7. It produces no change on solutions of alum or lime, but decomposes a solution of terra ponderosa in acetous acid, and the compound is totally insoluble in water. 8. It precipitates of a white colour solutions of iron, zinc, and copper, in the vitriolic acid; silver, quicksilver, and lead, in that of nitre; and lead in the acid of sea-salt. Tin combined with the same acid is thrown down of a blue colour; but corrosive sublimate and solutions of gold undergo no change. 9. On calcining the acid of tungsten in a crucible, it loses its solubility in water. 10. It turns black by calcination with inflammable matters and with sulphur, but in other respects continues unaltered. 11. Solution of hepar sulphuris is precipitated of a green colour by this acid, and the phlogisticated alkali white; the latter precipitate being soluble in water. On the addition of a few drops of muriatic acid to a solution of the acid

Acid of lapis ponderoſus and its combinations.

acid of tungſten in water, and ſpreading the liquor on poliſhed iron, zinc, or even tin, it acquires a beautiful blue colour; and the ſame thing happens when theſe metals are put into the acid. 12. It differs from the acid of molybdæna in not being volatile in the fire;

971 Differences betwixt the acid of tungſten and molybdæna.

in having little attraction for phlogiſton or ſulphur; in turning lime yellow, and forming an inſoluble compound with it as well as with ponderous earth. It has alſo a ſtronger attraction for lime than the acid of molybdæna; for if a combination of lime and acid of molybdæna be digeſted in a ſolution of the ammoniacal ſalt formed by uniting the acid of tungſten with volatile alkali, the latter expels the former, and produces regenerated tungſten. 13. By uniting the acid of tungſten to a calcareous earth, a regenerated tungſten is conſtantly procured.

972 Bergman's opinion concerning the acids of tungſten and molybdæna.

Mr Bergman obſerves, that the acid earth of tungſten is nearly allied to that of molybdæna; and both are in a ſtate much reſembling that of white arſenic. "It is well known (ſays he) that arſenic, in its ſemimetallic ſtate, is nothing but a peculiar acid ſaturated with phlogiſton; and that the white calx is an intermediate ſtate between acid and metal, containing juſt phlogiſton enough to coagulate the acid, but remaining ſtill ſoluble in water, and ſhowing ſigns of acidity. If a concluſion from analogy be admiſſible, all the other metals ſhould conſiſt in a combination of the ſame nature of the different radical acids, which with a certain quantity of phlogiſton are coagulated to a dry earthy ſubſtance; and on full ſaturation are reduced to the ſtate of complete metals."

973 Why he ſuppoſed the acids to be metallic earths.

The reaſons which induced Mr Bergman to ſuppoſe that the acids in queſtion are metallic earths, are as follow: 1. They both ſhow a ſtriking reſemblance to white arſenic in form, in producing effects like acids, and in their difficult ſolubility in water. 2. Their ſpecific gravity; that of arſenic being 3750, the earth of molybdæna 3460, and the acid of tungſten 3000. 3. Their precipitation with phlogiſticated alkali; a property hitherto deemed peculiar to metallic calces. Arſenic alſo, properly diſſolved in muriatic acid, gives, with the phlogiſticated alkali, a precipitate ſoluble in water, in the ſame manner as the acid of tungſten. 4. From their property of tinging vitreous matters; which, as well as that of precipitating with the phlogiſticated alkali, is reckoned to be a peculiar property of metals. The acid of tungſten produces by itſelf ſome effervescence with mineral alkali. With microcoſmic ſalt it produces a globule at firſt of a light blue; more of the acid makes it a dark blue; but ſtill it remains free from redneſs by refraction. A further addition makes it brown. Borax requires a ſlight tinge of blue, and with more of the acid becomes of a yellowiſh brown colour; but remains tranſparent, provided no further addition be made. This ultimate brown colour cannot be driven off either by nitre or the point of the flame urged by a blow-pipe. Acid of molybdæna is no leſs powerful; for with microcoſmic ſalt it produces a beautiful green colour: borax well ſaturated with it appears grey when viewed by the reflected rays, but of a dark violet by the refracted.

§ 15. *Of the Acid of* Milk.

It is univerſally known, that in the ſummer-time milk grows ſour and thick in a few days, and that this ſourneſs continues for ſome time to increaſe. It is ſtrongeſt after a fortnight has elapſed; after which, if the whey be filtered and evaporated to one-half the quantity, a few curds will ſtill ſettle to the bottom. By ſaturating the whey with volatile alkali, a ſmall quantity of animal earth precipitates; and the ſame thing takes place on the addition of lime-water. On the addition of a ſmall quantity of acid of tartar, the latter ſoon becomes partially ſaturated with vegetable alkali, and is converted into tartar. Thus the acid of milk beſides its proper acid part, contains animal earth and vegetable alkali in a looſe ſtate, and which is attracted by the acid of tartar; beſides all theſe it has alſo a ſmall quantity of the ſame alkali ſaturated with muriatic acid. It is no eaſy matter to ſeparate theſe ſubſtances from one another; becauſe the acid is not ſufficiently volatile to riſe in diſtillation by a gentle heat, nor are its principles ſufficiently fixed to bear the action of a ſtrong fire. With the one therefore it remains almoſt entirely in the retort, and with the other it is deſtroyed. Mr Scheele therefore uſed the following proceſs.

Acid of milk and its combinations.

974 Milk moſt ſtrongly acid after ſtanding a fortnight.

975 Component principles of ſour whey.

976 Scheele's method of procuring the pure acid of milk.

He evaporated ſour whey till only one-eighth part remained; when the cheeſy part being totally ſeparated, he ſtrained the acid; and in order to obtain the animal earth, ſaturated the liquor with lime, diluting the ſolution with a triple quantity of water. In order to ſeparate the lime, he employed the acid of ſugar, which has a ſtronger attraction than any other for lime. This earth therefore being ſeparated, the matter was evaporated to the conſiſtence of honey, and highly rectified ſpirit of wine poured upon it to diſſolve the acid part; which being accompliſhed, the other ſaline ſubſtances were left by themſelves: and, laſtly, the acid ſolution being diluted with pure water, and the ſpirit ſeparated by diſtillation, the pure acid remained in the retort.

977 Properties of this acid.

The properties of the acid of milk are, 1. Evaporated to the conſiſtence of a ſyrup, it yields no cryſtals; and when evaporated to dryneſs, it deliqueſces. 2. By diſtillation it yields firſt water, then a weak acid like ſpirit of tartar; afterwards ſome empyreumatic oil, with more of the ſame acid, fixed air, and inflammable air; in the retort was left a fixed coal. 3. By ſaturation with fixed vegetable alkali it yields a deliqueſcent ſalt, ſoluble in ſpirit of wine. 4. A ſalt of a ſimilar kind is obtained by combining it with mineral alkali. 5. With volatile alkali a deliqueſcent ſalt is produced, which by diſtillation yields a great deal of its alkali before the acid is deſtroyed by heat. 6. It forms deliqueſcent ſalts with terra ponderoſa, lime, and clay; but with magneſia it forms ſmall cryſtals, which, however, are again deliqueſcent. 7. It has no effect either by digeſtion or boiling on biſmuth, cobalt, regulus of antimony, tin, quickſilver, or gold. However, after digeſtion with tin, it precipitated gold from its ſolution in aqua-regia, in the form of a black powder. 8. It diſſolves iron and zinc, producing inflammable air during the ſolution. The liquor produced by the diſſolution of iron was brown, and yielded no cryſtals; but the ſolution of zinc cryſtallizes. 9. Copper diſſolved in this acid communicates to the liquor firſt a blue, then a green, and then a dark blue colour, without cryſtallizing. 10. Lead was diſſolved after ſome

Acid of milk and its combinations.

some days digestion; the solution had a sweet astringent taste, and would not crystallize. A small quantity of white matter fell to the bottom, which on examination was found to be vitriol of lead.

978 It seems to be of the acetous kind.

"From these experiments (says Mr Scheele) it appears, that the acid of milk is of a peculiar kind; and though it expels the vinegar from the acetated vegetable alkali, yet it seems destined, if I may so speak, to be vinegar; but from the want of such substances as, during fermentation, produce some spirituous matter, it seems not to be volatilized, though a portion of it indeed arrives at this point, and really becomes vinegar: for without a previous spiritous fermentation, or without brandy, there never arises any vinegar.

979 Milk capable of complete fermentation.

But that the milk enters into a complete fermentation though there be no sign of brandy present, appears from the following experiment: If a bottle full of fresh milk be inverted into a vessel containing so much of the same liquor that the mouth of the bottle reaches below the surface of the latter, and if you expose this bottle to a degree of heat a little greater than our summer, you will find, in the space of 24 hours, that the milk is not only coagulated, but in part expelled out of the bottle; and that in a couple of days afterwards, the aerial acid extricated from the milk will have expelled the greater part of it. It was said above, that the acid of milk cannot be converted into vinegar, from the want of such substances as during fermentation produce brandy;

979 Converted into vinegar.

which appears to be evident from this: If to a kanne of milk you add five spoonfuls of good brandy, and expose the vessel, well corked, in such a manner, however, that you now and then give vent to the air developed during fermentation, you will find in a month, sooner or latter, that the whey will be changed into good vinegar, which, strained through a cloth, may be kept in bottles."

980 Acid of sugar of milk how procured.

The acid of sugar of milk is considerably different from that just now described. To procure it, Mr Scheele poured 12 ounces of diluted nitrous acid on four ounces of finely powdered sugar of milk contained in a glass retort, to which a receiver was adapted. The retort was placed in a sand-bath, and as soon as the mixture acquired a certain degree of heat, it began to effervesce violently; for which reason, the retort and receiver were taken away from the fire. The mixture, however, continued to grow hotter and hotter, with a great emission of dark red vapours continually increasing, for half an hour. A considerable quantity of nitrous air and aerial acid were extricated during that time. Care must be taken, therefore, to have the retort and receiver both of a sufficient size, and not to make the luting too tight. When the effervescence had subsided, the retort was again placed in the sand-bath, and the nitrous acid thus distilled off till the mass acquired a yellowish colour; on which the retort was immediately taken away from the fire. In two days time the solution seemed to have undergone no remarkable change, nor was there any appearance of crystals. Eight ounces more of the same nitrous acid were therefore added, and the whole exposed to the same degree of heat as before. When the mass grew warm, another effervescence, though weaker than the former, ensued; the yellow colour disappeared, and the nitrous acid was again abstracted, till the solution, which had been rendered opaque by the appearance of a white powder in it, assumed a yellowish colour, on which the retort was again removed from the sand. After it was grown cool, the mass in the retort was found to be inspissated; it was redissolved in eight ounces of water, and filtered. Seven and a half drachms of white powder remained on the filter; the solution which passed through the filter was very acid. It was evaporated to the consistence of a syrup, four ounces more nitrous acid poured upon it, and the evaporation repeated in a sand-heat. After the whole was cool, some small long acid crystals were found, together with a small quantity of white powder which was separated from it, and some more nitrous acid poured on the remaining mass, and on evaporation, more such crystals made their appearance. The same process was repeated several times; by which means the whole mass was at last changed into such crystals, and weighed about five drachms, showing in every respect the same phenomena produced by acid of sugar. The white powder, weighing seven and a half drachms, was the true acid of sugar of milk; and its properties are,

981 Properties of this acid.

1. It burns in a red hot-crucible like oil, without leaving behind it any mark or ashes. 2. It dissolves in boiling water in the proportion of one of salt to 60 of the liquid. 3. One fourth part of the dissolved powder separates from the liquid on cooling, in form of very small crystals. 4. Half an ounce of the salt was dissolved in a glass vessel in 30 ounces of boiling water, and the solution filtered when cold. It had a sourish taste, reddened the tincture of lacmus, and effervesced with chalk. 5. Two drachms of the salt exposed to an open fire in a glass retort, melted, grew black, and frothed very much; a brown salt was found sublimed into the neck of the retort, which smelled like a mixture of salt of benzoin and salt of amber, eleven grains of coal remaining in the retort. The receiver contained a brown liquid without any mark of oil, smelling like the sublimed salt. It contained also some of the salt dissolved, which was separated from it by a gentle evaporation. The sublimed salt weighed 35 grains, had a sour taste, and was easily soluble in spirit of wine, but with more difficulty in water, and burned in the fire with a flame. 6. Concentrated vitriolic acid, distilled with this salt, became very black, frothed much, and decomposed the salt entirely. 7. Acid of sugar of milk, gradually added to a hot solution of alkali, occasioned an effervescence and coagulation in consequence of the formation of a vast number of crystals, which require eight times their weight of water to dissolve them, and separate again in a great measure from the liquid on cooling. The same phenomena took place with the mineral alkali, only the salt was somewhat more soluble, requiring only five times its weight of water for solution. If to a solution of it a solution of alkali of tartar be added, a number of small crystals will soon be formed at the bottom of the vessel, on account of the greater attraction of this acid with the vegetable alkali. 8. With volatile alkali it forms a kind of sal ammoniac, which, after being gently dried, has a sourish taste. By distillation, the volatile alkali is first separated, the lime-water precipitates, and the residuum yields the same products by distillation as the pure acid. 9. With all the earths, acid of sugar of milk forms insoluble salts.

Lithifiac acid and its combinations.

falts. If a folution of ponderous earth in muriatic or nitrous acid be dropped into a folution of acid of fugar of milk, the former is inftantly decompofed, and the earth falls to the bottom in combination with the acid of faccharum lactis. The fame phenomena take place with folutions of lime in the nitrous and marine acids; but folution of gypfum is not decompofed. The fame alfo takes place with folutions of magnefia in vegetable or mineral acids, and with earth of alum; all of which are decompofed by the neutral falts abovementioned. 10. The folution of this acid, by reafon of the fmall quantity diffolvable in water, has no fenfible effects on metals in their perfect ftate; but when they are reduced to calces, it then acts upon them, and forms falts, very little or not at all foluble in water. Silver, mercury, and lead are precipitated in form of a white powder; blue, green, and white vitriol, as well as manganefe combined with acid of vitriol, are not precipitated; but all metallic folutions are precipitated by the neutral falts.

§ 16. *Of the* LITHISIAC *Acid, or Acid of the human Calculus.*

982 Calculi all of the fame nature.

THE calculi examined by Mr Scheele, with a view to difcover their conftituent parts, were, as he informs us, all of the fame nature, whether flat and polifhed, or rough and angular. A fmall quantity of calculus in powder was put into a retort, and fome diluted vitriolic acid, poured upon it. The powder was not affected by a digefting heat; however, it was diffolved when the humidity was abftracted by diftillation. After the diffipation of the acid, a black coal was left in the retort, and the vitriolic acid which had paffed into the receiver was become fulphureous. The marine acid, whether diluted or concentrated, had no effect upon the calculus, not even when boiled with it. The nitrous acid diluted, or aquafortis, had fome effect on the calculus, even when cold. On the application of heat, an effervefcence enfued with red vapours, and the calculus was diffolved. Repeating the experiment in a retort with lime-water, the latter was precipitated. The folution of calculus is acid, though the menftruum be boiled with a fuperabundant quantity of powder, fo that there may remain a portion of it un-

983 Properties of the acid of calculus.

diffolved. It produces deep red fpots on the fkin in half an hour after it is applied; and if the faturated folution be a little more evaporated, it affumes of itfelf a blood-red colour, which however, difappears on dropping in a fingle drop of nitrous acid. Terra ponderofa is not precipitated by it from the muriatic acid; nor are metallic folutions fenfibly changed. With alkalies it becomes fomewhat more yellow when the alkali is fuperabundant. The mixture, in a ftrong digefting heat affumes a rofe colour, and ftains the fkin in the fame manner, without any fenfation of burning. The mixture likewife precipitates metals of different colours; vitriol of iron, black; of copper, green; folution of filver, grey; corrofive fublimate, zinc, and lead, of a white colour. Lime water precipitates a white powder foluble in muriatic and nitrous acids without effervefcence; and though there be an excefs of precipitated powder, the folution will be acid. This white powder, therefore, is the acid of the calculus itfelf, the exiftence of which is alfo confirmed by Mr Bergman's experiments. The further analyfis of this is related under the article CALCULUS, below.

Flowers of benzoin, &c.

§ 17. *Of the* FLOWERS *of* BENZOIN, *Acid of* LEMONS, *with other anamolous vegetable acids, and the refemblance which the vegetable acids in general bear to one another.*

984 Flowers of benzoin obtained by fublimation.

IT has long been known, that the refinous fubftance, improperly called gum benzoin, yields by fublimation with a gentle heat a quantity of fine faline matter of a moft agreeable odour, and flightly acid tafte, called *flowers* of *benzoin*. Another method of obtaining

985 By lixiviation.

this fubftance is by lixiviating the gum with water, and cryftallizing the falt. Mr Scheele, determined to

986 Quantities obtained by both methods.

try what quantity of the flowers could be obtained from the refin, found that, by fublimation, he was able to obtain from one pound of benzoin between nine and twelve drachms of flowers. By lixivation the quantity obtained was confiderably lefs than the former, owing to the faline particles being fo much covered by the refin, that the water could not have fuffi-

987 Attempts to procure all the flowers the refin is capable of yielding.

cient accefs to diffolve them all. It was next attempted to procure all the flowers which the benzoin was capable of yielding. This was firft done by boiling pounded chalk and benzoin in water, and then filtering the decoction; but no cryftals appeared. On pouring fome drops of vitriolic acid into the liquor, the falt

988 Boiling with chalk infufficient;

of benzoin foon afterwards precipitated (for this falt, which is an acid, was united to the chalk); but the quantity of falt was no greater than that obtained by lixiviation. Alkaline ley was next tried, and the fo-

989 And with alkaline ley.

lution faturated with an acid. Thus the falt of benzoin was obtained by precipitation; but here this inconvenience was met with, that the powder of benzoin ran together during the boiling, and floated on the

990 Boiling with lime the beft method.

furface like a tenacious refin. One only method, therefore, remained to be tried, and that was to boil the benzoin with quick-lime; and as the particles of lime, by interfperfing themfelves betwixt thofe of the benzoin would prevent their running together, and lime has likewife the property of acting upon the refinous particles, this feems to be the beft method of procuring the flowers of benzoin in the greateft quantity, and alfo of the beft quality; and thus we may obtain from 12 to 14 drachms of flowers from a pound of

991 Mr Scheele's receipt for preparing the flowers of benzoin by this method.

benzoin. Mr Scheele's receipt for preparing them after this new method, is as follows: "Pour 12 ounces of water upon four of unflaked lime, and after the ebullition is over, add eight pounds (of 12 ounces each) of water; put then a pound of finely powdered refin of benzoin into a tinned pan, pour upon it firft about fix ounces of the lime-water abovementioned; mix them well together, and thus add all the reft of the lime-water in fucceffion. The reafon of adding the lime water thus by portions, is, that if it be poured in all at once, it will not mix with the benzoin, which will likewife coagulate and run together into a mafs. This mixture muft be boiled over a gentle fire for half an hour, agitating it conftantly; then taking it from the fire, let it ftand quiet for fome time to fettle, after which the clear liquor is to be poured off into a glafs veffel. Pour then eight pounds of water more upon the lime in the veffel, and ufe this lime-water as before, repeating this procefs twice more, making four times in

Flowers of benzoin, &c.

in all; and lastly, putting all the residuum together on a filter, pour hot water upon them. During this process, the calcareous earth of the lime-water combines with the acid of benzoin, and separates it from the resinous particles of this substance; but a small quantity of resin is dissolved by the lime-water, and gives it a yellow colour.

"All these liquors being mixed together and boiled down to two pounds, are then to be strained into another glass vessel. They are inspissated so far, because the superfluous water would hold a great quantity of the salt in solution; and a little of the resin being soluble in a large quantity of lime-water, but not in a small, falls to the bottom on the liquor being inspissated. When the liqour has become cold, after being strained the last time, add muriatic acid till the flowers be totally precipitated, which happens by reason of the stronger attraction of the marine acid for the calcareous earth. The precipitated coagulum is then to be put upon a filter; and, after being well dried, to be edulcorated sufficiently, by repeatedly pouring cold water upon it, when it must be dried with a gentle heat. As the water made use of for this purpose, however, is capable of dissolving a little of the salt of benzoin, it ought to be evaporated, and afterwards set to crystallize. In order to give this salt a shining appearance, let it be dissolved in a sufficient quantity, six, ounces, for instance, of water by gentle boiling; then strain it immediately, while yet warm, through a cloth, into a glass vessel which has been heated before; and thus a number of fine crystals will shoot as soon as the solution is grown cold. The water is then to be strained from the crystals, and the rest of the salt suspended in the water may be obtained by repeated evaporation and crystallization. In this method, however, a great quantity of the flowers are lost by reason of their volatility; it will therefore be more convenient to keep them in the form of their original precipitate, which is always in fine powder. Cloth answers best for the filtration of the hot solution: when blotting paper is used, the salt sometimes crystallizes in the filter, and obstructs it. The filteration itself might be omitted, were it not that about two grains of resin of benzoin remain united to the liquor, from whence it cannot be separated but by the operation just mentioned."——The properties of this salt as an acid are but little known. It has a most agreeable flavour; which, however, ceases as soon as it unites with calcareous earth, but is recovered again on being separated by any other acid.

992 Flavour of the flowers may be taken away and produced at pleasure.

With regard to the other vegetable acids, they may be divided into the essential, the fermented, and empyreumatic. The essential acids are pure, as exemplified in those of lemons, sorrel, and sorrel-dock; or but little altered by the admixture of other matters, as those of cherries, barberries, tamarinds, &c. In sweet fruits they are generally so much covered when ripe as scarce to be distinguished: however, these latent acids become more evident, partly in fermentation, and partly by dry distillation. By the former method, all flowers, excepting a few which bear cruciform flowers, are made to yield vinegar; and by dry distillation only a very few yield a volatile alkali.

993 Anomalous vegetable acids how divided.

994 Of the essential acids.

The acid which passes over in dry distillation is scarce perceptible while the subject retains its natural form; but when once produced, has the same essential qualities with the other; whence it was naturally supposed that all vegetable acids are at bottom the same. Chemists, however, have been divided in their opinions on this subject; some supposing that the acid of sugar or of tartar is the basis, and others that vinegar is the basis of them all. In proof of this latter hypothesis, it has been urged, that the acid of lemons may be crystallized; of which we have the following account in Scheele's Essays. "The juice will not shoot into crystals by mere evaporation, even when thickened to the consistence of a syrup. This our author supposed to proceed from the great quantity of mucilaginous matter with which the juice abounds; for which reason he mixed the inspissated juice with strong spirit of wine which coagulated the whole: but even thus he could obtain no crystals by evaporation. He therefore employed the method used for procuring the pure acid of tartar, and which is formerly described. The lemon juice, while boiling, was saturated with pulverised chalk, and the compound immediately fell to the bottom in a form nearly resembling tartarised lime. To separate the acid, a quantity of oil of vitriol, equal in weight to the chalk employed, but diluted with ten times it weight of water was necessary. This mixture must be boiled in a glass vessel for a few minutes; and when grown cold, the acid is to be separated from the gypsum by filtration. In order to crystallize it, we must evaporate the whole to the consistence of a thin syrup; but great care is to be taken, lest any of the calcareous earth remain in the evaporated liquour: to determine which, a little of it is to tried with fresh oil of vitriol, which will throw drown the remainder: and in this case some more must be added to the whole quantity; for the least particle of lime remaining prevents the crystallization, while the superfluous quantity of oil of vitriol, if too much happens to be added, remains in the liquor. The crystals shoot equally well in a hot as in a cold temperature, which is very unusual."

995 Empyreumatic acids.

996 Whether the acid of sugar or of tartar is the basis of vegetable of acids.

997 Dr Crell's method of crystallizing the acid of lemons.

998 The crystallization prevented by the smallest particle of lime.

It is very remarkable that this crystallized salt of lemons cannot be converted into acid of sugar by means of that of nitre, though the extract of the juice itself may. Sour cherries afford acid of sugar, and another salt supposed to be tartar; and a kind of sugar may be obtained not only from roots of various kinds, but from fine raisins, and, as Dr Crell thinks, from expressed must; but whether the saccharine acid can be procured from this kind of sugar in equal quantity as from the common, or even whether it yields the same products with common sugar by dry distillation, is still a matter of doubt.

999 Salt of lemons cannot be converted into acid of sugar.

Pure acid of tartar yields on distillation *per se* an empyreumatic acid, and a coal consisting of oily particles and calcareous earth. Dr Crell therefore asks, May not the acetous acid be mere acid of tartar, which did not meet with alkaline salt and earth enough with which it might combine and become more fixed; but, on the contrary, attracted more subtile oily particles, and thus become more volatile? In distilling terra foliata tartari in the dry way, the acid of vinegar which enters its composition is almost entirely destroyed, only $\frac{1}{11}$th of pure acid being obtained, the residuum in the retort, as well as the rest of that which comes over into the receiver, being entirely alkakine; and the same

1000 Product of acid of tartar by dry distillation.

1001 Acetous acid almost entirely destoyed by fire.

Identity of the vegetable acids, &c.

ſame thing happens to the acid of tartar, the empyreumatic acid abovementioned being extremely weak. Mr Beaumé likewiſe informs us, that if any calcareous earth, egg-ſhells, for inſtance, be diſſolved in vinegar, and the cryſtallized ſalt be diſtilled, we obtain $\frac{23}{64}$ of a red and very fiery inflammable fluid, ſmelling like empyreumatic acetous ether, which reddens tincture of turnſole. Muſt, diſtilled before fermentation, yields only an empyreumatic acid reſembling ſpirit of tartar. The conjecture therefore ſeems reaſonable, that vinegar and tartar have for their baſis the ſame ſpecies of acid, which in the caſe of vinegar is combined with a greater proportion of oil, and in tartar with more earth.

1002 Requiſites for bringing vinegar nearer the ſtate of tartar.

To bring vinegar therefore nearer the ſtate of tartar, we muſt deprive it of its fine volatilizing phlogiſton, combine it with more fixed matter, and reſtore its groſſer oil. All this, however, is extremely difficult to be effected.

1003 Mr Weſtrumb's unſucceſsful attempt.

Mr Weſtrumb, who attempted it, added nitrous acid in various proportions, but could only produce a phlogiſtication of the latter, and dephlogiſtication of the vinegar; but as he could not think of any method of ſeparating the two acids from one another, he was unable to inveſtigate the properties of vinegar thus dephlogiſticated.

1304 Dr Crell's opinion of the poſſibility of tranſmutation.

Dr Crell is of opinion, that this might have been done by vegetable alkali, lime, and terra ponderoſa. The nitrous acid, with vegetable alkali, would have ſhot into the ordinary hexangular cryſtals of nitre: the acetous acid would have formed a compound not eaſily cryſtallized, provided it had remained unchanged; and, though it had approached the nature of ſaccharine acid, would ſtill have formed a compound difficultly cryſtallizable. The effects of theſe acids, indeed, on lime, are directly oppoſite to what they are on terra ponderoſa. With the former, nitrous acid forms a liquor which can ſcarce be cryſtallized; with the latter it produces ſalts difficult to be diſſolved: while the acetous acid, with terra ponderoſa, forms deliqueſcent ſalts; with lime, ſuch as effloreſce in the air. But if the vinegar, by means of the operation already mentioned, had been made to approach towards the nature of acid of ſugar, tranſparent cryſtals would immediately have fallen by reaſon of the ſtrong attraction of this acid for lime.

1005 Method recommended by him for attempting the experiment.

Dr Crell therefore recommends the following method. Let nitrous acid be ſeveral times diſtilled off from vinegar; and when the former, upon being newly added, produces no more red vapours, ſaturate the liquor with lime or terra ponderoſa, ſeparating the ley, which will not ſhoot, from the cryſtals. The nature of the ſalt which does not contain nitrous acid, may be determined from the figure of its cryſtals, or from the effects of other ſalts in conſequence of a double elective attraction. We might likewiſe add freſh nitrous acid to the ſeparated ſalt, or to the whole mixture, without any ſeparation of the nitrous ſalt, till the earthy ſalt, which does not contain any nitrous acid, be ſaturated. The vinegar, if unaltered by the operation, would riſe on diſtilling the liquor; and if converted into ſaccharine acid, would not be diſlodged from lime by ſpirit of nitre. In like manner, diſtilled vinegar ſhould be ſaturated with chalk, the compound reduced to cryſtals, and then expoſed to as ſtrong a fire as it can bear without expelling the acid, in order to diſſipate ſome phlogiſtic particles. Let it then be diſſolved, filtered, and cryſtallized again; after which it may be treated with nitrous acid as above directed. "Perhaps (ſays Dr Crell), the acetous acid may by this combination acquire more fixity; ſo that the nitrous acid ſhall be able to produce a greater change. Should it paſs over again in the form of acetous acid unchanged, let it be combined once more with calcareous earth; and let the foregoing experiment be repeated, in order to try whether ſome ſenſible change will not enſue. Should this method fail, try the oppoſite; that is, endeavour to add more groſs phlogiſtic matter to the vinegar. Try to combine ſtrong vinegar, and that which has been diſtilled, with unctuous oils. Thus we might perhaps bring it nearer to tartar; and again, by means of nitrous acid, convert it into acid of ſugar.

1006 His attempts to prove that all the vegetable acids may be reduced to one.

In another diſſertation on this ſubject, Dr Crell undertakes to ſhow, that all the vegetable acids may be converted into one, and that this is contained in the pureſt ſpirit of wine. The following are adduced as proofs.

1007 From the reſiduum of dulcified ſpirit of nitre.

1. If the reſiduum of dulcified ſpirit of nitre be boiled with a large quantity of nitrous acid, care being taken at the ſame time to condenſe the vapours by a proper apparatus; and if the liquid which has paſſed over be ſaturated with vegetable alkali, nitre and terra foliata tartari will be obtained; and on ſeparating the latter by means of ſpirit of wine, the vinegar may be had in the ordinary way of decompoſing the ſalt.

2. On boiling the reſiduum over again with nitrous acid, the ſame products are obtained; and the more frequently this proceſs is repeated, the leſs acid of ſugar is procured, until at length no veſtige of it is to be met with.

1008 From the decompoſition of acid of ſugar.

3. Pure acid of ſugar, boiled with 12 or 14 times its quantity of nitrous acid, is entirely decompoſed, and the receiver is found to contain phlogiſticated nitrous acid, vinegar, fixed air, and phlogiſticated air, while a little calcareous earth remains in the retort.

1009 From the production of acid of tartar from the reſiduum of dulcified ſpirit of nitre.

4. Acid of ſugar is likewiſe decompoſed by boiling with ſix times its quantity of vitriolic acid. In the receiver we find vinegar phlogiſticated with vitriolic acid, aërial acid; while pure vitriolic acid remains in the retort.

5. By ſaturating the reſiduum of dulcified ſpirit of nitre with chalk, there is formed an inſoluble ſalt, which by treatment with vitriolic acid yields a real acid of tartar, conſtituting a cream of tartar with vegetable alkali.

1010 From the production of empyreumatic acid of tartar from the liquor in which tartarous ſelenite is boiled.

6. On evaporating the liquor from which the tartareous ſelenite was obtained, a dark-coloured matter remains, yielding on diſtillation an empyreumatic acid of tartar, and a ſpongy coal. Hence it would ſeem, that ſpirit of wine conſiſts of acid of tartar, of water, and phlogiſton; ſo that it is a native dulcified acid: and nitrous acid, on being mixed with it in moderate quantity, diſlodges the acid of tartar. On the addition of more nitrous acid, the acid of tartar is reſolved into acid of ſugar and phlogiſton; and by a ſtill greater addition, the ſaccharine acid is changed into vinegar.

1011 From the ſolution of mangane ſe by nitrous acid and acid of ſugar.

7. On boiling one part of the acid of ſugar with one and an half of mangane ſe and a ſufficient quantity of

nitrous

Acid of fat.

nitrous acid, the mangan[e]ſe will be almoſt entirely diſſolved, and phlogiſticated nitrous acid along with vinegar will paſs over into the receiver.

8. On boiling together acid of tartar, manganeſe, and nitrous acid, we obtain a ſolution of the manganeſe, with phlogiſticated nitrous acid and vinegar as before.

1012 From the ſolution of the ſame with vitriolic acid and that of tartar.

9. If acid of tartar be boiled along with vitriolic acid and manganeſe, the latter will be diſſolved, and vinegar with vitriolic acid will paſs over into the receiver.

1013 From the digeſtion of acid of tartar with ſpirit of wine.

10. On digeſting acid of tartar and ſpirit of wine for ſeveral months, the whole is converted into vinegar, the air in the veſſel being partly converted into cretaceous acid, and partly into phlogiſticated air.

1014 From the ſolution of manganeſe with vitriolic acid and ſpirit of wine.

11. On boiling ſpirit of wine with vitriolic acid and manganeſe, it will be converted into vinegar and phlogiſticated air.

1015 From the diſtillation of ſpirit of wine with cauſtic alkali.

12. By diſtilling ſpirit of wine upwards of 20 times from cauſtic alkali, it was changed into vinegar, and a conſiderable quantity of water was obtained.

Hence it appears, ſays Dr Crell, that the acids of tartar, ſugar, and vinegar, are modifications of the ſame acid, as it contains more or leſs phlogiſton. The acid of tartar has the greateſt quantity, the acid of ſugar ſomewhat leſs, and vinegr the leaſt of all. In theſe experiments, however, care muſt be taken that neither the nitrous acid nor fixed alkali employed contain any marine acid, otherwiſe the reſults will be uncertain.

§ 18. *Of the Acid of Fat.*

2d 1015 How procured.

THIS may be obtained from ſuet by means of many repeated diſtillations. A ſmall quantity is ſeparated at each diſtillation; but by diſtilling the empyreumatic oil into which the ſuet is thus converted over and over, a freſh quantity is always obtained. The acid of fat in ſome reſpects has a reſemblance to that of ſea-ſalt; but in others is much more like the vegetable kind, as being deſtructible in a ſtrong fire, forming compounds which do not deliqueſce with calcareous earth, and uniting intimately with oily ſubſtances.

3d 1015 Its effects on alkalies, &c.

With alkalies it forms ſalts entirely different from thoſe yielded by the other acids; with the volatile alkali, particularly, it produces a concrete volatile ſalt. When ſaturated with calcareous earth, it yields brown cryſtals; and a ſalt of the ſame kind was obtained by Dr Crell from a mixture of quicklime and ſuet diſtilled to dryneſs, and boiling up the reſiduum with water. The cryſtals were hexagonal, and terminated by a plane ſurface; their taſte was acrid and ſaltiſh; they did not deliqueſce in the air, and were eaſily and copiouſly diſſolved in water. With magneſia and earth of alum a gummy maſs is obtained, which refuſes to cryſtallize.

4th 1015 On metals.

With regard to the metals, Dr Crell informs us, that the acid of fat copiouſly diſſolves manganeſe into a clear and limpid liquor. It diſſolves the precipitate of cobalt, but not the regulus. White arſenic is acted upon but ſparingly, and nickel not at all, though it forms a green ſolution with the precipitate from nitrous acid. Regulus of antimony, by the aſſiſtance of heat is diſſolved into a clear liquor, which became milky in the cold: it cryſtallized on evaporation, and did not deliquate in the air. Zinc readily diſſolved, and imparted a peculiar metallic taſte, falling to the bottom in the form of a white powder on the addition of an alkali. Biſmuth in the metallic ſtate was not diſſolved; but the precipitate was. It acted upon mercury after being twice diſtilled from it, and poured afreſh upon the metal. The mercury could not be entirely precipitated by common ſalt. It acted more vigorouſly upon a precipitate from corroſive ſublimate; from the ſolution of which a white ſublimate was obtained after the liquor had been drawn off by diſtillation. A gold-coloured ſolution was obtained from platina by diſtilling the acid from it to dryneſs, and then pouring it back again; the precipitate of this metal from aqua-regia by ſpirit of wine was diſſolved in great abundance. Iron was very eaſily diſſolved in it, and exhibited a liquor of an aſtringent taſte, which ſhot into needle-like cryſtals that did not deliqueſce in the air. Lead was corroded and rendered the acid turbid. Minium was converted into a white powder, and then diſſolved with greater eaſe. The ſolution has a ſweet taſte, and cannot be precipitated by ſea-ſalt. Tin was corroded into a yellow calx, and diſſolved but in very ſmall quantity. Copper was diſſolved, even in the cold, into a green liquor; but the ſolution was greatly promoted by heat. On evaporation it ſhowed ſome diſpoſition to cryſtallize, but again attracted moiſture from the air. Silver-leaf was attacked only in a very ſmall degree; however, ſome was precipitated by means of copper, and the marine acid rendered the liquor turbid. The calx precipitated from aquafortis was diſſolved more copiouſly. Silver was precipitated of a white colour from aquafortis by the pure acid itſelf, as well as by its ammoniacal ſalt. Half an ounce of the acid diſtilled four times almoſt to dryneſs from ſome gold-leaves, and at length poured back upon them, the precipitate of a dilute ſolution of tin obtained by it, gained only a faint colour, rather inclining to red; but a mixture of two parts of acid with one of aquafortis, diſſolved gold very readily.

Fixed alkaline ſalts and their combinations.

§ 19. *Of Fixed ALKALINE SALTS.*

OF theſe there are two kinds; the vegetable and mineral. The former is never found by itſelf, and but rarely in combination with any acid; but is always prepared from the aſhes of burnt vegetables. It is got in the greateſt quantity from crude tartar; from which, if burned with proper care and attention, we may obtain one pound of alkali out of $2\frac{1}{4}$ of the tartar. The latter is found native in ſome parts of the earth. It is likewiſe found in very large quantities combined with the marine acid, in the waters of the ocean, and in the bowels of the earth; thus forming the common alimentary ſalt. It is alſo produced from the aſhes of certain ſea-plants, and of the plant called *kali;* from whence both the mineral and vegetable alkalies have taken their name. 1016 How procured.

The vegetable alkali difficultly aſſumes a cryſtalline form; nevertheleſs, it may be partially united with ſome acids in ſuch a manner as to cryſtallize, and loſe its property of deliquating in the air, without at the ſame time ceaſing to be an alkali. Of this we have an example in the acid of ants abovementioned. Something 1017 Vegetable alkali cryſtallized.

Fixed alkaline ſalts and their combinations.

thing of the ſame kind we have obſerved in treating vegetable fixed alkali with ſpirit of wine. A gallon of pretty ſtrong ſpirit of wine being drawn over from a pound of ſalt of tartar, a black unctuous liquor was left, which ſhot into cryſtals very much reſembling vitriolated tartar, and which did not deliquate in the air, but were nevertheleſs ſtrongly alkaline. Dr Black, however, informs us, that the vegetable alkali may be ſhot into fine cryſtals; but which cannot be preſerved, on account of their great attraction for moiſture, unleſs cloſely ſhut up from the air. They have not ſuch a quantity of water as to undergo the aqueous fuſion.

The mineral alkali in its natural ſtate always aſſumes a cryſtalline form, ſomewhat reſembling that of ſal mirabile. It does not deliquate in the air, nor does it ſeem to have ſo ſtrong an attraction for water, even when in its moſt cauſtic ſtate, as the vegetable alkali: hence mineral alkali is preferable to it in making ſoap,
1018 which is always of a firmer conſiſtence with mineral than with vegetable alkali. If vegetable alkali is combined with ſpirit of ſalt, ſome change ſeems to be thereby induced upon it; as the ſalt produced by expelling the marine acid by means of the vitriolic, and then cryſtallizing the maſs, cryſtallizes differently from vitriolated tartar. Whether the vegetable alkali might by this means be entirely converted into the mineral, deſerves a further inquiry.

Change on the vegetable alkali.

1019
Difference between vegetable and mineral alkalies.

Both mineral and vegetable alkalies, when applied to the tongue, have a very ſharp, pungent, and urinous taſte; but the vegetable conſiderably more ſo than the mineral. They both unite with acids, and form different neutral ſalts with them: but the vegetable alkali ſeems to have rather a greater attraction for acids than the other; although this difference is not ſo great as that a neutral ſalt, formed by the union of mineral alkali with any acid, can be perfectly decompoſed by an addition of the vegetable alkali, unleſs in conſiderable exceſs.

1020
Compoſed of a cauſtic ſalt and fixed air.

Both vegetable and mineral alkali appear to be compoſed of an exceedingly cauſtic ſalt united with a certain quantity of fixed air. This may be increaſed ſo far, as to make the vegetable alkali aſſume a cryſtalline form, and loſe great part of its alkaline properties: but as the adheſion of great part of this air is very ſlight, it eaſily ſeparates by a gentle heat. Some part, however, is obſtinately retained; and the alkali cannot be deprived of it by the moſt violent calcination *per ſe*. The only method of depriving it entirely of its fixed air is, by mixing an alkaline ſolution with quicklime.

Fixed Alkalies COMBINED,

1021
Hepar ſulphuris.

I. *With Sulphur*. The produce of this is the red fetid compound called *hepar ſulphuris*, or liver of ſulphur. It may be made by melting ſulphur with a gentle heat, and ſtirring into it, while melted, four times its weight of dry alkaline ſalt. The whole readily melts and forms a red maſs of a very fetid ſmell, and which deliquates in the air. If ſulphur is boiled in a ſolution of fixed alkaline ſalt, a like combination will take place.

In this proceſs, when the hepar is made either in the dry or the moiſt way, the fixed air of the alkali is diſcharged, according to Dr Prieſtley's obſervation. Neither does a fixed alkali, when combined with fixed air, ſeem capable of uniting with ſulphur; nor will the union be accompliſhed without heat, unleſs the alkali is already in a cauſtic ſtate. Hence a cold ſolution of hepar ſulphuris may be decompounded, partly at leaſt, by fixed air. On adding an acid, however, the decompoſition takes place much more rapidly; and the ſulphur is precipitated to the bottom, in form of a white powder. 1022

Decompoſed.

During the precipitation of the ſulphur from an alkali, by means of acids, a thick white ſmoke ariſes, of a moſt fetid ſmell and ſuffocating nature. It burns quietly, without exploſion, on a candle's being held in it. Calces of ſilver, lead, iron, or biſmuth, are rendered black by it. Hence, if any thing is wrote with a ſolution of lead, and a ſolution of hepar ſulphuris is paſſed over it when dry, the writing, formerly inviſible, will immediately appear of a blackiſh brown colour. Silver, in its metallic ſtate, is prodigiouſly blackened either by the contact of this vapour, or by being immerſed in a ſolution of the hepar ſulphuris itſelf. Litharge is inſtantly reſtored to its metallic ſtate, on being immerſed even in a cold ſolution of hepar ſulphuris. 1023

Inflammable vapour in the compoſition of it.

1024
Phlogiſton of ſulphur diſpoſed to quit the acid.

By being united with an alkali, the acid of ſulphur ſeems very much diſpoſed to quit the phlogiſton. If a ſolution of hepar ſulphuris is expoſed to the air for ſome time, it is ſpontaneouſly decompoſed; the phlogiſton of the ſulphur flying off, and the acid remaining united with the alkali into a vitriolated tartar. This decompoſition takes place ſo remarkably, when liver of ſulphur is diſſolved in water, that, by a ſingle evaporation to dryneſs, it will be almoſt totally changed into vitriolated tartar. If this ſubſtance, in a dry ſtate, be expoſed to a moderate degree of heat, and the maſs kept conſtantly ſtirring, a like decompoſition will follow; the phlogiſton of the ſulphur will fly off, and the acid unite with the alkali.

1025
Metals and charcoal diſſolved by it.

Liver of ſulphur is a great ſolvent of metallic matters; all of which, except zinc, it attacks, particularly in fuſion. It ſeems to diſſolve gold more effectually than other metals. This compound alſo diſſolves vegetable coals, even by the humid way; and theſe ſolutions, if ſuffered to ſtand in the open air, always precipitate a black powder, no other than the coal they had diſſolved, in proportion to the quantity of hepar ſulphuris decompoſed. When vegetable coal is thus diſſolved by liver of ſulphur in fuſion, it is of a much deeper red than in its natural ſtate. The ſolution in water is of a green colour.

1026
Soap.

II. *With Expreſſed Oils*. The reſult of this combination is *ſoap*; for the preparation of which in large quantities in the way of trade, ſee SOAP. The ſoap which is uſed in medicine is prepared without heat, in the following manner, according to the author of the Chemical Dictionary.

"One part of quicklime, and two parts of good Spaniſh ſoda (the ſalt prepared from the aſhes of the herb kali), are boiled together during a ſhort time in an iron caldron. This lixivium is to be filtered, and evaporated by heat, till a phial, capable of containing an ounce of water, ſhall contain an ounce and 216 grains of this lixivium. One part of this lixivium is to be mixed with two parts of oil of olives, or of ſweet almonds, in a glaſs or ſtone-ware veſſel. The mixture ſoon becomes thick and white; and muſt be ſtirred from time to time with an iron ſpatula. The combination

Fixed alkaline falts and their combinations. nation is gradually completed, and in feven or eight days a very white and firm foap is obtained."

In attempting combinations of this kind, it is abfolutely neceffary that the alkali be deprived of its fixed air as much as poffible; otherwife the foap will be quite unctuous and foft: for fixed alkalies have a greater attraction for fixed air than for oil, and hence foap is decompounded by blowing fixed air into a folution of it in water. It may be made either with tallow, wax, fpermaceti, butter of cocoa, the coarfer refinous fubftances, or animal oils.

1027 Starkey's foap. III. *With Effential Oils.* The volatility of thefe oils in a great meafure hinders them from being acted upon by alkalies: neverthelefs, combinations of this kind have been attempted; and the compounds fo produced have been called *Starkey's foap*, from one Starkey a chemift, who endeavoured to volatilize falt of tartar by combining it with oil of turpentine. His method was to put dry falt of tartar into a matrafs, and pour upon it effential oil of turpentine to the height of two or three fingers breadth. In five or fix months, a part of the alkali and oil were combined into a white faponaceous compound. This muft be feparated from the mixture, and more of it will afterwards be formed by the fame method.

Chemifts, imagining this foap to be poffeffed of confiderable medical virtues, have endeavoured by various methods to fhorten this tedious procefs. Of thefe one of the moft expeditious is that recommended by Mr Beaumé; which confifts in triturating, for a long time, alkaline falt upon a porphyry, and adding oil of turpentine during the trituration. According to him, the thick refinous part of the oil only can combine with the falt; and, during the time this combination is effected, the more fubtile and attenuated parts will fly off. Hence he finds that the opeartion is confiderably abridged by the addition of a little turpentine or common foap. The moft expeditious of all, however, is that mentioned by Dr Lewis; which confifts in heating the alkali red hot, and then throwing it into oil of turpentine, ftirring them well together; on which they immediately unite into a faponaceous mafs.

This kind of foap is fubject to great alterations from keeping; particularly the lofs of its colour, and a kind of decompofition occafioned by the extraction of an acid from the oil of turpentine, which unites with the alkali, and cryftallizes not only all over the furface, but in the very fubftance of the foap. The nature of this falt is unknown, but certainly deferves confideration.

1028 Phlogifticated alkalies. IV. *With Phlogifton.* This combination is effected by calcining them with the charcoal either of vegetable or animal matters. The confequence is, that they are greatly altered in their properties; fometimes fo much as to be enabled to precipitate calcareous earths from their folutions in acids. Metallic folutions precipitated by them in this ftate, affume different colours.

Differences obferved between Fixed Alkalies obtained from different *Vegetables*.

Thefe differences we muft conceive to arife from fome proportion of the oily and phlogiftic matter of the vegetable remaining in the afhes from whence the falts are extracted; for when reduced to their utmoft purity, by repeated calcinations in a ftrong fire, and deliquations in the air, all of them, the marine alkali excepted, appear to be the very fame. Fixed alkaline falts and their combinations.

1029 Mr Gmelin's experiments. On this fubject Mr Gmelin has given a great number of experiments in the fifth volume of the *Commentaria Petropolitana*; and found very confiderable differences, not only between the alkaline falts, but likewife the pure vegetable earths obtained from different vegetables by burning. The falts of the feveral plants examined were prepared with great care, and all of them exactly in the fame manner; each vegetable being burnt in a feparate crucible, with the fame degree of fire, till no remains of coaly matter could any longer be perceived; and the afhes elixated in glafs veffels with cold diftilled water. The falts, thus obtained, were found to produce different colours on mixture with certain liquors, and to effervefce in very different degrees with acids: certain metallic folutions were by fome precipitated, by others only rendered thicker, by others both precipitated and rendered thick; whilft fome occafioned neither the one nor the other of thefe changes, but left the fluid clear and tranfparent. Thus, with the vitriolic acid, the falts of fouthernwood and fage ftruck a pale brown colour; thofe of pine-tops and rue, a yellow; that of fern, a reddifh yellow; and that of fanicle, a dark leek-green: that of dill yielded a leek-green precipitate, with elegant green flakes floating in the liquor. This laft falt alfo gave a greenifh precipitate with the marine acid, and a red one with the nitrons. Solution of corrofive fublimate was changed yellow by falt of fouthernwood; of a brownifh colour, by that of colt's-foot; of a deep red, by that of wormwood; and of a pitch-colour, by that of dill. That of fern threw down an opal-colour; of fage, a fulphur-yellow; of elder flowers, a citron yellow; of fanicle, a faffron colour; and of milfoil, a deep-red precipitate. From folution of filver, falt of *carduus benedictus* threw down a white; of camomile, a grey; of hyffop, a brownifh; of dill, a blackifh brown; of fcabious, a yellowifh; and that of pine-tree tops, a fulphur yellow precipitate. Solution of vitriol of copper was changed by falt of fouthernwood to a bright fea-green; by that of dill, to an unfightly green; of agrimony, to a greenifh blue; and by that of milfoil, to a bright fky-blue: the falt of penny-royal made the liquor thick as well as blue, and that of feverfew made it thick and green: the falt of hyffop threw down a green precipitate, that of fcurvy-grafs a blue one, and that of fumitory a greenifh blue: whilft the falt of fern made fcarcely any change either in the colour or confiftency of the liquor.

§ 19. *Of Volatile Alkali.*

1030 Whence obtained. This is a kind of falt obtained from all animal, fome vegetable, fubftances, from foot by diftillation with a ftrong heat, and from all vegetable fubftances by putrefaction. Though a volatile alkali is procurable from all putrid animal fubftances by diftillation, yet the putrefactive procefs does not feem to prepare volatile alkali in all of thefe. Putrid urine, indeed, contains a great quantity of alkali ready formed, whence its ufe in fcouring, &c. but the cafe is not fo with putrid blood or flefh. Thefe afford no alkali till after the phlegm has arifen; and this they would

Volatile alkali and its combinations.

would do, though they had not been putrefied. According to Mr Wiegleb, volatile alkali is found in limestone, lapis suillus, chalk, marble, coals, turf, loam, clay, and many other kinds of earth. Its existence in these substances may be discovered merely by distilling them with a brisk fire, but still better by the addition of some quantity of fixed alkali or quicklime before the distillation.—It has even been found in all mineral salts and their acids, as vitriol, nitre, common salt, and the acid liquors drawn from these substances, also in gypsum and sulphur: from all which it may be separated by means of quicklime.—In the vegetable kingdom it is produced by dry distillation from mustard-seed, elder flowers and leaves; the leaves of the wild cherry-tree, white water-lilies, tobacco, and sage; as well as from many other plants. According to our author, the plainest proof of its existing almost universally in the vegetable kingdom, is, that the soot of our chimneys affords a volatile alkali by distillation, either with or without quicklime.

Volatile alkali, when pure, appears of a snowy whiteness; has a very pungent smell, without any disagreeable empyreuma; is very easily evaporable, without leaving any residuum; effervesces with acids much more strongly than fixed alkali; and forms with them neutral compounds called *ammoniacal salts*, which we have already described, and which are different according to the nature of the acid made use of; for all volatile alkalies, when perfectly purified, appear to be the very same, without the smallest difference.

Like fixed alkalies, these salts contain a great quantity of fixed air, on which their solidity depends; and which may be so increased as perfectly to neutralize, and deprive them of their peculiar taste and smell. When neutralized by fixed air, they have a very agreeable pungent taste, somewhat resembling that of weak fermenting liquors. When totally deprived of fixed air, by means of lime, they cannot be reduced to a solid form; but are dissipated in an invisible and exceedingly pungent vapour, called by Dr Priestley *alkaline air*. When volatile alkaline salt is dissolved in water, the solution is called *volatile alkaline spirit*.

Distillation and Purification of *Volatile Alkalies*.

1031 Distilling vessel, and method of performing the operation.

The materials most commonly used for preparing volatile alkalies are the solid parts of animals, as bones, horns, *&c.* These are to be put into an iron pot of the shape recommended for solution; to this must be fitted a flat head, having a hole in the middle about two inches diameter. From this a tube of plate-iron must issue, which is to be bent in such a manner that the extremity of it may enter an oily jar, through an hole made in its upper part, and dip about half an inch under some water placed in the lower part. The mouth of the jar is to be fitted with a cover, luted on very exactly; and having a small hole, which may be occasionally stopped with a wooden peg. The junctures are to be all luted as close as possible, with a mixture of clay, sand, and some oil; and those which are not exposed to a burning heat, may be further secured by quicklime and the white of an egg, or by means of glue. A fire being now kindled, the air contained in the distilling vessel is first expelled, which is known by the bubbling of the water; and to this vent must be given by pulling out the wooden peg. A considerable quantity of phlegm will then come over, along with some volatile alkali, a great quantity of fixable air, and some oil. The alkali will unite with the water, and likewise some part of the fixed air, the oil swimming above. A great many incoercible vapours, however, will come over, to which vent must be given from time to time, by pulling out the peg. The distillation is to be continued till all is come over; which may be known by the cessation, or very slow bubbling of the water. The iron pipe must then be separated from the cover of the distilling vessel, lest the liquid in the jar should return into it, on the air being condensed by its cooling. In the jar will be a volatile spirit, more or less strong according as there was less or more water put in, with an exceedingly fetid black oil floating upon it.

1032 Rectification.

The rectification of the volatile alkali is most commodiously performed at once by combining it with an acid; and, as spirit of salt has the least affinity with inflammable matter, it is to be chosen for this purpose, in preference to the vitriolic or nitrous. As the spirit is excessively oily, though already much weakened by the admixture of the water in the jar, if a very large quantity was not originally put in, an equal quantity of water may still be added, on drawing off the spirit. That as little may be lost as possible, the spirit should be received in a stone bottle; and the marine acid, likewise in a distilled state, added by little and little, till the effervescence ceases. The liquor, which is now an impure solution of sal ammoniac, is to be left for some time, that the oil may separate itself; it is then to be filtered, evaporated, and crystallized in a leaden vessel. If the crystals are not sufficiently pure at the first, they will easily become so on a second dissolution.

1033 Volatile sal ammoniac.

From sal ammoniac thus obtained pure, the volatile alkali may be extricated by distillation with chalk, alkaline salts, or quicklime. Alkaline salts act more briskly than chalk, and give a much stronger volatile alkali. The strength of this, however, we know may be altered at pleasure, by adding to, or depriving it of, its natural quantity of fixed air. Hence, perhaps, the best method would be, to prepare volatile alkalies altogether in a fluid state, by means of quicklime; and then add fixed air to them, by means of an apparatus similar to that directed by Dr Priestley for impregnating water with fixed air. To prevent lime from adhering to the distilling vessels in which it is put, the translator of Wiegleb's chemistry recommends the putting in three or four ounces of common salt along with the other ingredients.

Volatile alkalies COMBINED,

1034 Cuprum ammoniacale.

I. *With Metals.* There are only three metals, *viz.* copper, iron, and lead, upon which, while in their metallic form, volatile alkalies are capable of acting. Copper-filings are dissolved by volatile alkali, especially in its caustic state, into a liquor of a most admirable blue colour. It is remarkable, that this colour depends entirely upon the air having access to the solution: for if the bottle containing it is close stopt, the liquor becomes colourless; but, however, resumes its blue colour on being exposed to the air. On evaporation, a blue saline mass is obtained, which, mixed with fats, or other inflammable matters, tinges their flame green, leaving a red calx of copper, soluble again in volatile spirits as at first. This saline substance

Volatile alkali and its combinations.

ſtance has been received into the laſt edition of the Edinburgh Diſpenſatory, under the name of *cuprum ammoniacale*, as an antiepileptic.

1035 Copper, fulminating.

The blue mixture of ſolution of copper in aquafortis with volatile ſpirits, yields ſapphire-coloured cryſtals, which diſſolve in ſpirit of wine, and impart their colour to it. If, inſtead of cryſtallization, the liquor be totally evaporated, the remaining dry matter explodes, in a moderate heat, like aurum fulminans. This is given as a fact by Dr Lewis; but hath not ſucceeded upon trial by Dr Black. Various phenomena, ſays Mr Wiegleb, occur in the diſſolution of copper by the volatile alkali.—On ſaturating dilute ſpirit of ſal ammoniac with copper-filings, cryſtals are formed of a dark-blue colour, but which, by expoſure to the air, fall to pieces and become green. Vinous ſpirit of ſal ammoniac impregnated with copper, loſes in an inſtant its blue colour, on the affuſion of an equal quantity of ſaturated ſolution of fixed alkaline ſalt. The copper is then taken up by the fixed alkaline ſolution, which of conſequence acquires a blue colour, while the ſpirit of wine, deprived of the metal, floats clear on the top. When filings of copper are put into a bottle, and that bottle quite filled with cauſtic volatile alkali, and is immediately ſtopped up, no ſolution takes place: but when the bottle is left open, only for a ſhort time, or an empty ſpace is left in it, a colourleſs ſolution is obtained, which in the air obtains a blue colour; but which may be deprived of this colour as often as we pleaſe, by ſhutting it up exactly from the air, and letting it ſtand, in this ſituation, on freſh filings of copper.—From theſe phenomena Mr Wiegleb concludes, that copper does not diſſolve in volatile alkali until it has loſt part of its phlogiſton, to which the air, by the attraction it exerts upon it, contributes its ſhare. If this has taken place only in a ſmall proportion, and the farther acceſs of air be prevented, the remainder will be diſſolved without any colour; which, however, appears in the inſtant that, by a freſh acceſſion of air, the phlogiſton ſtill remaining finds means to eſcape. The diſſolved copper is always precipitated when the ſolution meets with phlogiſticated copper. The colourleſs ſolution is precipitated by zinc and vitriolic acid, but not by iron. It taſtes rather ſweet, and does not ſmell very ſtrong of volatile alkali; while, on the contrary, the blue ſolution has a pungent ſmell, and is precipitated by diſtilled water.

On the other two metals the action of volatile alkali is by no means ſo evident; it diſſolves iron very ſlowly into a liquor, the nature of which is not known; and lead is corroded by it into a mucilaginous ſubſtance.

II. *With Inflammable Subſtances.* With expreſſed oils, the cauſtic volatile alkali unites into a ſoft unctuous maſs, of a very white colour, imperfectly ſoluble in water, and which is ſoon decompoſed ſpontaneouſly. Compoſitions of this kind are frequently

1036 Sal volatile oleoſum.

uſed for removing pains, and ſometimes with ſucceſs. With eſſential oils, volatile alkalies may be united, either in their dry or liquid form, by means of diſtillation. The produce is called *ſal volatile oleoſum*; it is much more frequently uſed in a liquid than in a dry form. The general method of preparation is by diſtilling volatile alkali along with eſſential oils and ſpirit of wine, or the aromatic ſubſtance from whence the eſſential oils are drawn. Theſe compoſitions are variable at pleaſure; but certain forms are laid down in the diſpenſatories, with which it is expected that all the chemiſts ſhould comply in the preparation of theſe medicines.

1037 Spiritus volatilis ſuccinatus.

III. *Eau de Luce.* This is the name given to an exceedingly volatile ſpirit, which ſome years ago was pretty much in vogue; and indeed ſeems very well calculated to anſwer all the purpoſes for which volatile alkalies can be uſed. It was of a thick white colour, and ſmelled ſomewhat of oil of amber. A receipt appeared in Lewis's Diſpenſatory for the preparation of this fluid, under the name of *ſpiritus volatilis ſuccinatus*. The method there directed, however, did not ſucceed; becauſe, though the alkaline ſpirit is capable of keeping a ſmall quantity of oil of amber ſuſpended, the colour is greatly more dilute than that of genuine eau de luce. In the Chemical Dictionary we have the following receipt: "Take four ounces of rectified ſpirit of wine, and in it diſſolve 10 or 12 grains of white ſoap; filter this ſolution; then diſſolve in it a drachm of rectified oil of amber, and filter again. Mix as much of this ſolution with the ſtrongeſt volatile ſpirit of ſal ammoniac, as will be ſufficient, when thoroughly ſhaken to give it a beautiful milky appearance. If upon its ſurface be formed a cream, ſome more of the oily ſpirit muſt be added."

This receipt likewiſe ſeems inſufficient. For the oil of amber does not diſſolve in ſpirit of wine: neither is it probable that the ſmall quantity of ſoap made uſe of could be of any ſervice; for the ſoap would diſſolve perfectly in the alkaline ſpirit, without ſuffering any decompoſition. The only method which we have found to anſwer is the following. Take an ounce, or any quantity at pleaſure, of balſamum Canadenſe; place it in a ſmall china baſon, in a pan of boiling water, and keep it there till a drop of it taken out appears of a reſinous conſiſtence when cold. Extract a tincture from this reſin with good ſpirit of wine; and having impregnated your volatile ſpirit with oil of amber, lavender or any other eſſential oil, drop in as much of the ſpiritous tincture as will give it the deſired colour. If the volatile ſpirit is very ſtrong, the eau de luce will be thick and white, like the cream of new milk; nor is it ſubject to turn brown with keeping

1038 Volatile alkali combined with ſulphur.

IV. *With Volatile Tincture of Sulphur.* This is a combination of the cauſtic volatile alkali, or ſpirit of ſal ammoniac, with ſulphur. It is uſually directed to be made by grinding lime with the ſulphur and afterwards with the ſal ammoniac, and diſtilling the whole in a retort, but the produce is by this method very ſmall, and even the ſucceſs uncertain. A preferable method ſeems to be, to impregnate the ſtrongeſt cauſtic volatile ſpirit with the vapour which ariſes in the decompoſitions of hepar ſulphuris by means of an acid, in the ſame manner as directed for impregnating water with fixed air.

1039 Sympathetic ink.

This preparation has a moſt nauſeous fetid ſmell, which ſpreads to a conſiderable diſtance; and the effluvia will blacken ſilver or copper, if barely placed in the neighbourhood of the unſtopped bottle. This property renders it capable of forming a curious kind of ſympathetic ink; for if paper is wrote upon with a ſolution of ſaccharum ſaturni, the writing, which diſappears when dry, will appear legible and of a brownish

Phenomena from mixtures of acid, &c. ſalts.

browniſh black, by barely holding it near the mouth of the bottle containing volatile tincture of ſulphur. The vapours of this tincture are ſo exceedingly penetrating, that it is ſaid they will even penetrate through a wall, ſo as to make a writing with ſaccharum ſaturni appear legible on the other ſide; but this is much to be doubted. It is even ſaid that it cannot penetrate through the ſubſtance of paper, but only inſinuates itſelf betwixt the leaves; and hence if the edges of the leaves are glued together no black colour will appear.

§ 20. *Of the* Phenomena *reſulting from different mixtures of the Acid, Neutral, and Alkaline* Salts, *already treated of.*

1040 Of mixing the acid ſpirits with one another.

1. If concentrated oil of vitriol is mixed with ſtrong ſpirit of nitre, or ſpirit of ſalt, the weaker acid will become exceedingly volatile, and emit very elaſtic fumes; ſo that if a mixture of this kind is put into a cloſe ſtopt bottle, it will almoſt certainly burſt it. The ſame effect follows upon mixing ſpirit of ſalt and ſpirit of nitre together. In this caſe, both acids become ſurpriſingly volatile; and much of the liquor will be diſſipated in fumes, if the mixture is ſuffered to ſtand for any conſiderable time. Such mixtures ought therefore to be made only at the time they are to be uſed.

1041 Diſſolving vitriolic ſalts in nitrous or marine acids.

2. If vitriolated tartar is diſſolved in an equal quantity of ſtrong ſpirit of nitre, by heating them together in a matraſs, the ſtronger vitriolic acid will be diſplaced by the weaker nitrous one, and the liquor, on cooling, will ſhoot into cryſtals of nitre. The ſame thing happens alſo upon diſſolving vitriolated tartar, or Glauber's ſalt, in ſpirit of ſalt. This obſervation we owe to Monſ. Beaumé, and the reaſon of it has been already explained. See n° 285.

1042 Decompoſition of vitriolic ſalts by ſolutions of earth, &c. in nitrous or marine acids.

3. If vitriolated tartar, or Glauber's ſalt, is diſſolved in water, and this ſolution mixed with another conſiſting of calcareous earth, ſilver, mercury, lead, or tin, diſſolved in the nitrous or marine acids, the vitriolic acid will leave the fixed alkali with which it was combined, and, uniting with the calcareous earth or metal, fall with it to the bottom of the veſſel. This decompoſition takes place only when the vitriolic acid meets with ſuch bodies as it cannot eaſily diſſolve into a liquid, ſuch as thoſe we have juſt now mentioned; for though vitriolated tartar is mixed with a ſolution of iron, copper, &c. in the nitrous or marine acids, no decompoſition takes place. The caſe is not altered, whatever acid is made uſe of; for the marine acid will effectually ſeparate ſilver, mercury, or lead, from the vitriolic or nitrous acids.

1043 By lime-water.

4. According to Dr Lewis, if a ſolution of vitriolated tartar is dropt into lime-water, the acid will unite with the lime, and precipitate with it in an indiſſoluble ſelenite, the alkali remaining in the water in a pure and cauſtic ſtate.

1044 Of green vitriol by ſaccharum ſaturni.

5. If green vitriol is mixed with any ſolution containing ſubſtances which cannot be diſſolved into a liquid by the vitriolic acid, the vitriol will be immediately decompoſed, and the liquor will become a ſolution of iron only. Thus, if green vitriol is mixed with a ſolution of ſaccharum ſaturni, the vitriolic acid immediately quits the iron for the lead, and falls to the bottom with the latter, leaving the vegetable acid of the ſaccharum ſaturni to combine with the iron.

1045 Of ſolution of tin by ſaccharum ſaturni.

6. If ſolution of tin in aqua-regia is mixed with ſolution of ſaccharum ſaturni, the marine acid quits the tin for the lead contained in the ſaccharum; at the ſame time, the acetous acid, which was combined with the lead, is unable to diſſolve the tin which was before kept ſuſpend by the marine acid. Hence, both the ſaccharum ſaturni, and ſolution of tin, are very effectually decompoſed, and the mixture becomes entirely uſeleſs. Dyers and callico-printers ought to attend to this, who are very apt to mix theſe two ſolutions together; and no doubt many of the faults of colours dyed or printed in particular places, ariſe from injudicious mixtures of a ſimilar kind. See Dyeing.

1046 Of calcareous ſolutions by mild volatile alkali.

7. If mild volatile alkali, that is, ſuch as remains in a concrete form, by being united with a large quantity of fixed air, is poured into a ſolution of chalk in the nitrous or marine acids, the earth will be precipitated, and a true ſal ammoniac formed. If the whole is evaporated to dryneſs, and a conſiderable heat applied, the acid will again part with the alkali, and combine with the chalk. Thus, in the purification of volatile alkalies by means of ſpirit of ſalt, the ſame quantity of acid may be made to ſerve a number of times. This will not hold in volatile ſpirits prepared with quicklime.

1047 Sal alembroth.

8. If equal parts of ſal ammoniac and corroſive ſublimate mercury are mixed together and ſublimed, they unite in ſuch a manner as never to be ſeparable from one another without decompoſition. The compound is called *ſal alembroth;* which is ſaid to be a very powerful ſolvent of metallic ſubſtances, gold itſelf not excepted. Its powers in this, or any other reſpect, are at preſent but little known. By repeated ſublimations, it is ſaid this ſalt becomes entirely fluid, and refuſes to ariſe in the ſtrongeſt heat.

1048 Solution of ſalts promoted by vitriolic acid.

9. If vitriolic acid is poured upon any ſalt difficult of ſolution in water, it becomes then very eaſily ſoluble. By this means, vitriolated tartar, or cream of tartar, may be diſſolved in a very ſmall quantity of water.

Sect. II. *Earths.*

The general diviſions and characters of theſe ſubſtances we have already given; and moſt of their combinations with ſaline ſubſtances have been mentioned, excepting only thoſe of the terra ponderoſa; a ſubſtance whoſe properties have been but lately inquired into, and are not yet ſufficiently inveſtigated. In this ſection, therefore we have to take notice only of their various combinations with one another, with inflammable, or metallic ſubſtances, &c. As they do not, however, act upon one another till ſubjected to a vitrifying heat, the changes then induced upon them come more properly to be treated of under the article Glass. Upon metallic and inflammable ſubſtances (ſulphur alone excepted), they have very little effect; and therefore what relates to theſe combinations ſhall be taken notice of in the following ſections. We ſhall here confine ourſelves to ſome remarkable alterations in the nature of particular earths by combination with certain ſubſtances, and to the phoſphoric quality of others.

Terra ponderoſa and its combinations.

§ 1. *The* Terra Ponderosa.

1049 Uſually found united with the vitriolic acid.

This earth is of the true calcareous kind, and capable of being converted into a very acrid lime; but in other reſpects is very different. It is moſt commonly met with in the veins of rocks, united with the vitriolic acid in a maſs ſomewhat reſembling gypſum, but much heavier and more opaque; and from the great weight of this ſubſtance the earth itſelf has its name, though when freed from the acid it is by no means remarkable for this property. Its properties were firſt taken notice of by the foreign chemiſts; but they have been more accurately inveſtigated by Dr Withering, who has publiſhed his obſervations in the 74th volume of the Philoſophical Tranſactions.

1050 Dr Withering's experiment.

His experiments were not made on the gypſeous ſubſtance abovementioned; but on a combination of the earth with fixed air, which is much more uncommon, and like the other poſſeſſes a very conſiderable degree of ſpecific gravity. Both theſe combinations have the general name of *ſpathum ponderoſum*, or *ponderous ſpar;* the former being alſo called *baroſelenite*, &c.

1051 Combination of terra ponderoſa with aërial acid deſcribed.

The ſpar uſed by Dr Withering was got out of a lead mine at Alſton moor in Cumberland. Its appearance was not unlike that of a lump of alum; but on cloſer inſpection it appeared to be compoſed of ſlender ſpiculæ in cloſe contact, more or leſs diverging, and ſo ſoft that it might be cut by a knife; its ſpecific gravity from 4.300 to 4.338. It effervesced with acids, and melted, though not very readily, under the blow-pipe.

1052 Effects of fire upon it.

In a common fire it loſt its tranſparency; and on being urged with a ſtronger heat in a melting furnace, it adhered to the crucible, and ſhowed ſigns of fuſion; but did not appear to have loſt any of its fixed air, either by diminution in weight, becoming cauſtic, or loſing its power of effervescing with acids.

1053 Treated with marine acid.

Five hundred grains of this ſpar, by ſolution in muriatic acid, loſt 104 grains in weight, and left an inſoluble reſiduum of three grains. In another experiment, 100 grains of ſpar loſt 21; and there remained only 0.6 of a grain of inſoluble matter.

On diſſolving another hundred grains in dilute muriatic acid, 25 ounce-meaſures of air were obtained, which by proper trials appeared to be pure aërial acid; and, on precipitating the ſolution with mineral alki, 100 grains of earth were again obtained; but on diſſolving the precipitate in freſh muriatic acid, only 20 ounce-meaſures of air were produced.

1054 Precipitated by mild and cauſtic fixed alkalies.

Mild vegetable alkali precipitated a ſaturated ſolution of this ſpar in marine acid, with the eſcape of a quantity of fixed air; and the ſame effect took place on the addition of foſſil alkali; but with cauſtic alkalies there was no appearance of effervescence, though a precipitate likewiſe fell.

Fifty parts of ſpar, diſſolved in marine acid, loſt $10\frac{1}{2}$; and with cauſtic vegetable alkali, a precipitate weighing $45\frac{1}{4}$ was obtained. Phlogiſticated alkali precipitated the whole of the earth, as appeared by the addition of mild fixed alkali afterwards, which occaſioned no farther precipitation.

1055 Convertible into lime capable of decompoſing vitriolic ſalts.

Part of the precipitate thrown down by the mild alkali was expoſed to a ſtrong heat in a crucible, and then put into water. The liquid was inſtantly converted into a very acrid lime-water, which had the following remarkable properties: The ſmalleſt portion of vitriolic acid, added to this water, occaſioned an immediate and copious precipitation, which appeared even after the liquid was diluted with 200 times its bulk of pure water. 2. A ſingle drop let fall into a ſolution of Glauber's ſalt, vitriolated tartar, alum, vitriolic ammoniac, Epſom ſalt, or ſelenite, occaſioned an immediate and copious precipitate in all of them: the reaſon of which was the ſuperior attraction of the ponderous earth for the acid of theſe ſalts, which forming with it an indiſſoluble concrete, inſtantly fell to the bottom.

Terra ponderoſa and its combinations.

1056 Inſoluble precipitate thrown down by cauſtic alkali.

The precipitate thrown down by the cauſtic vegetable alkali was put into water, but exhibited no ſuch appearances as the other: even the mixture was boiled; nor had it any acrimonious taſte. On adding the three mineral acids to ſeparate portions of the precipitate itſelf, neither effervescence, nor any ſign of ſolution, appeared. After ſtanding an hour, water was added, and the acids were ſuffered to remain another hour on the powder; but on decanting them afterwards, and adding foſſile alkali to the point of ſaturation, no precipitate appeared.

The precipitate thrown down by the phlogiſticated alkali, mixed with nitre and borax, and melted with a blow-pipe on charcoal, formed a black glaſs; on flint-glaſs, a white one; and on a tobacco-pipe, a yellowiſh white one. Another portion, melted with ſoap and borax in a crucible, formed a black glaſs.

The ſmall quantity of inſoluble reſiduum formerly mentioned, appeared to be the combination of ponderous earth with vitriolic acid, called *heavy* gypſum, marmor metallicum, baroſelenite, *&c.*

1057 Analyſis and properties of aërated ponderous ſpar.

From theſe experiments the Doctor concludes, that 100 parts of this ſpar contain 78.6 of pure ponderous earth, $\frac{6}{10}$ of a grain of marmor metallicum, and 20.8 grains of fixed air. 2. The quantity of mild alkali neceſſary to ſaturate any given portion of acid, contains a greater quantity of fixed air than can be abſorbed by that quantity of terra ponderoſa which the acid is able to diſſolve. 3. The terra ponderoſa, when precipitated by means of a mild alkali, readily burns to lime; and this lime-water proves a very nice teſt of the preſence of vitriolic acid. 4. In its native ſtate the terra ponderoſa will not burn to lime; when urged with a ſtrong fire, it melts and unites with the crucible, without becoming cauſtic; nor can it be made to part with its fixed air by any addition of phlogiſton. He conjectures, therefore, that as cauſtic lime cannot unite to fixed air without moiſture, and as this ſpar ſeems to contain no water in its compoſition, it is the want of water which prevents the fixed air aſſuming its elaſtic aerial ſtate. "This ſuppoſition (ſays he) becomes ſtill more probable, if we obſerve, that when the ſolution of the ſpar in an acid is precipitated by a mild alkali, ſome water enters into the compoſition of the precipitate; for it has the ſame weight as before it was diſſolved, and yet produces only 20 ounce-meaſures of fixed air, while the native ſpar contains 25 of the ſame meaſures: ſo that there is an addition of weight equal to five ounce-meaſures of air, or three one-half grains, to be accounted for; and this can only ariſe from the water. 5. The precipitate formed by the cauſtic alkali, taking ſome of the latter down with it, forms a ſubſtance neither ſoluble in acids nor water. This inſoluble compound is alſo formed by adding the lime-water already

Terra ponderosa and its combinations.

ready mentioned, to a solution of caustic vegetable, or fossile fixed alkali, but not with volatile alkali. 6. Fixed vegetable as well as mineral alkali, and even volatile alkalies, whether mild or caustic, are capable of separating terra ponderosa from any other acid excepting the vitriolic; but from it neither mild nor caustic alkalies are capable of separating this earth,
1058 excepting the vegetable fixed alkali, which will partly do it by an intense heat in the dry way. 7. This earth affords an excellent method of purifying the nitrous and marine acids from any portion of the vitriolic; for the attraction between terra ponderosa and this acid is so strong, that the least portion of the latter will be instantly detected by the lime-water above mentioned.

Terra ponderosa a test of the presence of vitriolic acid.

1059 *White matter contained in vitriolic acid found to be gypsum.*

The vitriolic acid, Dr Withering observes, is commonly adulterated with a white powder, which discovers itself by turning the liquor milky when the acid is diluted with water; and this powder he finds to be gypsum, from the following properties:

1. By repeated boiling in water, six grains and a half were reduced to two. 2. By gentle evaporation this solution afforded five grains of crystals as hard and tasteless as selenite. 3. A precipitate was formed by mild fossile alka on adding it to a solution of these crystals in water. 4. On exposing this powder to a pretty strong heat, and then putting it into water, the latter became acrid, and acquired the taste of lime-water. 5. The insoluble part suffered no change by boiling in nitrous acid: one half of it mixed with borax, and exposed to the blow-pipe upon charcoal, melted into glass; the other half, mixed with borax, and exposed to the blow-pipe upon charcoal, did the same; whence it appears, says our author, that the greatest part of this substance was calx vitriolate or selenite; the remainder a vitrifiable earth. He had before found, that the heavy gypsum, or marmor metallicum, would dissolve in concentrated vitriolic acid, but always separated upon the addition of water; and from his experiments it now appears that selenite does the same.

1060 *Experiments on the marmor metallicum.*

Dr Withering next proceeds to give a set of experiments on the heavy gypsum, marmor metallicum of Cronstadt, or the Baroselenite of others, already mentioned. The specimens he obtained were from Kilpatrick hills near Glasgow, and a sort with smaller crystals found among the iron ore about Ketley in Shropshire, and in the lead-mines at Alston-Moor. He describes it as white, nearly transparent, but without the property of double refraction; composed of laminæ of rhomboidal crystals, and decrepitating in
1061 the fire; the specific gravity from 4.402 to 4.440.

Description of a kind found near Edinburgh.

The specimens we have seen differ considerably from this description, being composed, to appearance, of thin laminæ; which all together form a very opaque white mass, which has not the least transparency unless split excessively thin. They are found about three miles to the southwest of Edinburgh, near Pentland hills, and likewise betwixt Edinburgh and Leith. In the former place they lie in small veins of a rock consisting of a kind of iron stone, and so closely adhering to it, that it would seem either that the stone is converted into the spathum ponderosum, or the latter into the stone. It is therefore often intermixed with the rock so intimately, that it is impossible to separate them perfectly from each other.

Dr Withering having exposed 100 grains of the marmor metallicum to a red heat for an hour, in a black crucible, found that it had lost five grains of its weight; but as a sulphureous smell was perceptible, he
suspected that a decomposition had taken place, and therefore exposed another portion to a similar heat in a tobacco-pipe, which had no smell of sulphur, nor was it diminished in weight. It melted with borax into a white opaque glass, but was barely fusible by 1062
itself under the blow pipe. It did not seem to dissolve in water, nor in any of the acids, except the vitriolic, when by long boiling it had become very concentrated and almost red hot. It then appeared perfectly dissolved; but separated again unchanged on the addition of water. On exposing the vitriolic solution to the atmosphere for some days, beautiful radiated crystals were formed in it. 1063

Effects of heat upon it.

May be dissolved in very concentrated vitriolic acid.

1064 *Precipitated from it unchanged by vegetable fixed alkali.*

On adding a solution of mild vegetable alkali to this vitriolic solution, a precipitate appeared; but it consisted of marmor metallicum unchanged. An ounce of it in fine powder was then fused with two of salt of tartar until it ran thin, when six drachms of a residuum insoluble in water were left. 1065 On the addition of nitrous acid, only 52 grains were left, which appeared to be marmor metallicum unchanged. On saturating the alkaline solution with distilled vinegar, and washing the precipitate, the liquor was found to contain terra foliata tartar, formed by the union of the acetous acid with part of the alkali; and of vitriolated tartar, formed by that of the alkali with the native acid of the marmor metallicum.

May be decomposed in the dry way by salt of tartar.

1066 *Nitrous solution shoots into fine crystals.*

The salt formed by the nitrous acid shot readily into beautiful permanent crystals of a rough bitterish taste. Some of the salt deflagrated with nitre and charcoal, left by washing the terra ponderosa very white, capable of being burnt into lime, and again forming an insoluble compound with vitriolic acid. An hundred grains of aerated terra ponderosa, dissolved in marine acid, and precipitated by the vitriolic, were augmented 17 grains in weight. Hence it appears, 1067

Analysis and properties of the marmor metallicum.

1. That the marmor metallicum is composed of vitriolic acid and terra ponderosa. 2. That this compound has very little solubility in water. 3. That it can only be dissolved in highly concentrated oil of vitriol, from which it separates unchanged on the addition of water. 4. That it cannot be decomposed in the moist way, by mild fixed alkali, though it may be so in the dry. 5. That it may be decomposed by the union of inflammable matter to its acid, by which sulphur is formed, though the acid cannot be dissipated by mere heat. 6. An hundred parts of this substance contain 32.8 of pure vitriolic acid, and 57.2 of terra ponderosa. The marmor metallicum, our author remarks, may possibly be useful in some cases where a powerful flux is wanted; for having mixed some of it with the black flux, and given the mixture a strong heat in a crucible, it ran entirely through the pores of the vessel. 1068

Cauk, a substance of this kind, found in Derbyshire in England.

Dr Withering describes two other kinds of this substance, known by the name of *cauk*, and found in the mines of Derbyshire, and other places. These differ from the other only in containing a small proportion of iron. On the whole, he concludes, that "the terra ponderosa seems to lay claim to a middle place betwixt the earths and metallic calces. Like the former-

Transmutation of flints into an earth soluble in acids.

mer it cannot be reduced to a metallic form, though like the latter it may be precipitated by phlogisticated alkali. In many of its properties it much resembles the calx of lead, and in others the common calcareous earth. Its most remarkable properties are its decomposing the vitriolic neutral salts, and forming, with the nitrous and marine acids, crystals which do not deliquesce.

§ 2. *Transmutation of* FLINTS *into an* EARTH *soluble in Acids.*

1069
Solution of flint.

THIS is effected by mixing powdered flints with alkaline salt, and melting the mixture by a strong fire. The melted mass deliquates in the air, like alkaline salts; and if the flint is then precipitated, it becomes soluble in acids, which it entirely resisted before.

In this process the alkali, by its union with the flint, is deprived of its fixed air, and becomes caustic. To this causticity its solvent power is owing; and therefore the flint may be precipitated from the alkali, not only by acids, but by any substance capable of furnishing fixed air; such as magnesia alba or volatile alkali. The precipitate in both cases proves the same; but the nature of it hath not hitherto been determined. Some have conjectured that the vitriolic acid existed in the flint; in which case, the alkali made use of in this process ought to be partly converted into vitriolated tartar.

1070
Solubility of this earth denied by Mr Bergman.

The above process is delivered on the authority of former chemists; but Mr Bergman, who has published a dissertation on this subject, asserts that it cannot be dissolved except by the fluor acid. The vitriolic, nitrous, or marine acids, have no effect upon it, even when newly precipitated from the liquor of flints washed and still wet, and though a thousand parts of

1071
Reason of the mistake of former chemists.

acid be added to one of the earth, and boiled upon it for an hour: but when three parts of alkaline salt are melted in a crucible with one of quartz, the salt dissolves at the same time about seven hundreth parts of its own weight of the clay which composes the crucible; and the solubility of this has given occasion to the mistake abovementioned. If the fusion be performed in an iron vessel, no soluble part will be obtained, excepting the very small portion of clay which the quartz contains; and when this is once exhausted by an acid, no more can be procured by any number of fusions with alkali.

1072
Crystals of flint artificially formed by Mr Bergman.

The fluor acid, he observes, is never obtained entirely free from siliceous earth, and consequently its power as a menstruum must be weakened in proportion to the quantity it contains. In order to observe its solvent power, however, our author, in the year 1772, put some quartz, very finely powdered, into a bottle containing ⅓ of a kanne of fluor acid. The bottle was then slightly corked, and set by in the corner of a room. Two years afterwards it was examined; and on pouring out the liquor there were found concreted at the bottom of the vessel, besides innumerable small prismatic spiculae, 13 crystals of the size of small peas, but mostly of an irregular form. Some of these resembled cubes, whose angles were all truncated, such as are often found in the cavities of flints. These were perfect siliceous crystals, and very hard, but not comparable with quartz, though they agreed with it in essential properties. "Possibly (says he) the length of a century may be necessary for them to acquire, by exsiccation, a sufficient degree of hardness. The bottom itself, as far as the liquor had reached, was found covered with a very thin siliceous pellicle, which was scarcely visible, but separated on breaking the bottle. It was extremely pellucid, flexible, and showed prismatic colours. These phenomena show that much siliceous matter is dissolved and suspended." (in the fluor acid). "Whether any of the quartz was taken up in this experiment is uncertain; but it appears probable that little or none was dissolved; since, by the help of heat during the distillation, the acid had previously taken up so much siliceous earth, that upon slow evaporation it was unable to retain it. Hence appears the origin of the crystals and the pellicle; and hence appears the cause which impedes the action of fluor acid upon flint; namely, that the acid obtained in the ordinary way is already saturated with it.

Transmutation of flints into an earth soluble in acids.

1073
Why the fluor acid will not dissolve flint directly.

1074
Siliceous earth most completely precipitated by volatile alkali.

The volatile alkali precipitates siliceous earth most completely from fluor acid: and thus we find, that one part of it is contained in 600. of the acid, diluted to such a degree, that its specific gravity is only 1.064. This precipitate has all the properties of pure flint; but that precipitated either by vegetable or mineral fixed alkali does not afford a pure siliceous earth, but a peculiar kind of triple salt, formed of the earth, fluor acid, and fixed alkali, which dissolves, though with difficulty, in warm water, especially the earth procured by vegetable alkali, but is easily decomposed by lime-water and lets fall the mineral fluor regenerated.

1075
A triple salt formed by precipitation with fixed alkali.

1076
Siliceous earth dissolved by boiling in solution of alkali.

Fixed alkaline salts attack this earth by boiling, but not unless it be reduced to very fine powder, and newly precipitated from the liquor. Oil of tartar per deliquium takes up about one-sixth of its weight, and the liquor becomes gelatinous on cooling, though at first diluted with 16 times its weight of water. This solution is effected only by the caustic part; for when fully saturated with fixed air, it cannot enter into any union with it. Volatile alkali, even though caustic, has no effect.

1077
Has a remarkable attraction for it in the dry way.

The attraction betwixt siliceous earth and fixed alkali is much more remarkable in the dry way; for thus it melts with one half its weight of alkali into an hard, firm, and transparent glass, the aerial acid and water going off in a violent effervescence. In proportion as the alkali is increased, the glass becomes more soft and lax, until at last it dissolves totally in water, as has been already mentioned. The siliceous matter thus precipitated is of a very rare and spongy texture, and so much swelled by water, and its bulk when wet is at least twelve times greater than when dry; nor does it contract more though suffered to remain a long time in the water. Hence it is easy to reduce the liquor of flints to a jelly, by diluting it with four or eight times its weight of water, and adding a sufficient quantity of precipitate; but if an over-proportion of water be used, for instance, 24 times the weight, the liquor will then remain limpid though we add as much acid as is sufficient for saturating the alkali. The reason of this Mr Bergman supposes to be, that the siliceous particles are removed to such a distance from one another, that they cannot overcome the

1078
Is very rare and spongy when precipitated.

1079
Why it cannot sometimes be precipitated by an acid without heat.

Phosphoric earths.

the friction they must necessarily meet with in their passage downwards through the fluid; but if the liquor be boiled, which at once diminishes its quantity and tenacity, the siliceous matter is instantly separated.

1080 Liquor of flints decomposed by too great a quantity of water, and by fluor acid

Liquor of flints is also decomposed by too great a quantity of water; for by this the efficacy of the menstruum is weakened, and it is also partly saturated by the aerial acid contained in the water. A precipitate also falls when the fluor acid is made use of; the reason of which is the same as the precipitation by other acids: in this case, however, the alkali makes part of the precipitate, as has been already observed; and therefore the matter which falls is fusible before the blowpipe, and soluble in a sufficient quantity of water.

§ 3. *Of* Phosphoric *Earths.*

1081 Bolognian stone.

These are so called from their property of shining in the dark. The most celebrated and anciently known of this kind is that called the *Bolognian stone*, from Bologna, a city in Italy, near which it is found. The discovery, according to Lemery, was accidentally made by a shoe-maker called *Vincenzo Casciarolo*, who used to make chemical experiments. This man, having been induced to think, from the great weight and lustre of these stones, that they contained silver, gathered some, and calcined them; when carrying them into a dark place, probably by accident, he observed them shining like hot coals.

Mr Margraaf describes the Bolognian stone to be an heavy, soft, friable, and crystallized substance, incapable of effervescence with acids before calcination in contact with burning fuel. These properties seem to indicate this stone to be of a selenitic or gypseous nature.

1082 How rendered luminous.

When these stones are to be rendered phosphoric, such of them ought to be chosen as are the cleanest, best crystallized, most friable and heavy; which exfoliate when broken, and which contain no heterogeneous parts. They are to be made red hot in a crucible; and reduced to a very fine powder in a glass-mortar, or upon a porphyry. Being thus reduced to powder, they are to be formed into a paste with mucilage of gum tragacanth, and divided into thin cakes. These are to be dried with a heat, which at last is to be made pretty considerable. An ordinary reverberating furnace is to be filled to three quarters of its height with charcoal, and the fire is to be kindled. Upon this charcoal the flat surfaces of the cakes are to rest, and more charcoal to be placed above them, so as to fill the furnace. The furnace is then to be covered with its dome, the tube of which is to remain open; all the coal is to be consumed, and the furnace is to be left to cool; the cakes are then to be cleansed from the ashes by blowing with bellows upon them. When they have been exposed during some minutes to light, and afterwards carried to a dark place, they will seem to shine like hot coals; particularly if the person observing them has been some time in the dark, or have shut his eyes, that the pupils may be sufficiently expanded. After this calcination through the coals, if the stones be exposed to a stronger calcination, during a full half hour, under a muffle, their phosphoric quality will be rendered stronger.

From attending to the qualities of this stone, and the requisites for making this phosphorus, we are naturally led to think, that the Bolognian phosphorus is no other than a composition of sulphur and quicklime. The stone itself, in its natural state, evidently contains vitriolic acid, from its not effervescing with acids of any kind. This acid cannot be expelled from earthy substances by almost any degree of fire, unless inflammable matter is admitted to it. In this case, part of the acid becomes sulphureous, and flies off; while part is converted into sulphur, and combines with the earth. In the abovementioned process, the inflammable matter is furnished by the coals in contact with which the cakes are calcined, and by the mucilage of gum tragacanth with which the cakes are made up. A true sulphur must therefore be formed by the union of this inflammable matter with the vitriolic acid contained in the stone; and part of this sulphur must remain united to the earth left in a calcareous state, by the dissipation, or conversion into sulphur, of its acid.

1083 Analysis of the phosphorus.

1084 All calcareous stones phosphoric, according to Mr du Fay.

In the year 1730, a memoir was published by Mr du Fay; wherein he asserts, that all calcareous stones, whether they contain vitriolic acid or not, are capable of becoming luminous by calcination: with this difference only, that the pure calcareous stones require a stronger, or more frequently repeated, calcination to convert them into phosphorus; whereas those which contain an acid, as selenites, gypsum, spars, *&c.* become phosphoric by a slighter calcination. On the contrary, Mr Margraaf asserts, that no other stones can be rendered phosphoric but those which are saturated with an acid; that purely calcareous stones, such as marble, chalk, limestone, stalactites, *&c.* cannot be rendered luminous, till saturated with an acid previously to their calcination.

1085 Signior Beccaria's observation.

We have already taken notice, that the compounds formed by uniting calcareous earths with the nitrous and marine acids become a kind of phosphori; the former of which emits light in the dark, after having been exposed to the sun through the day; and the latter becomes luminous by being struck. Signior Beccaria found, that this phosphoric quality was capable of being given to almost all substances in nature, metals perhaps excepted. He found that it was widely diffused among animals, and that even his own hand and arm possessed it in a very considerable degree. In the year 1775, a treatise on this kind of phosphori was published by B. Wilson, F. R. S. and member of the Royal Academy at Upsal. In this treatise he shows, that oyster-shells, by calcination, acquire the phosphoric quality in a very great degree, either when combined with the nitrous acid or without it.

1086 Mr Wilson's experiments.

The first experiment made by our author was the pouring some aquafortis, previously impregnated with copper, on a quantity of calcined oyster-shells, so as to form them into a kind of paste; he put this paste into a crucible, which was kept in a pretty hot fire for about 40 minutes. Having taken out the mass, and waited till it was cool, he presented it to the external light. On bringing it back suddenly into the dark, he was surprised with the appearance of a variety of colours like those of the rainbow, but much more vivid. In consequence of this appearance of the prismatic

 colours,

Vegetable earth.

colours, he repeated the experiment in various ways, combining the calcined oyſter-ſhells with different metals and metallic ſolutions, with the different acids, alkaline and neutral ſalts, as well as with ſulphur, charcoal, and other inflammable ſubſtances; and by all of theſe he produced phoſphori, which emitted variouſly coloured light.

1087 Surpriſing phoſphoric quality of oyſter-ſhells.

What is more remarkable, he found that oyſter-ſhells poſſeſſed the phoſphoric quality in a ſurpriſing degree; and for this purpoſe nothing more was requiſite than putting them into a good ſea-coal fire, and keeping them there for ſome time. On ſcaling off the internal yellowiſh ſurface of each ſhell, they become excellent phoſphori, and exhibit the moſt vivid and beautiful colours. As we know that neither the vitriolic nor any other acid is contained in oyſter-ſhells, we cannot as yet ſay any thing ſatisfactory concerning the nature of this phoſphorus.

§ 4. *Of the* Vegetable *Earth.*

1088 Dr Lewis's opinion.

This is produced from vegetables by burning, and, when perfectly pure, by lixiviating the aſhes with water, to extract the ſalt; and then repeatedly calcining them, to burn out all the inflammable matter; and is perhaps the ſame from whatever ſubſtance it is obtained: in this ſtate, according to Dr Lewis, it is of the ſame nature with magneſia. In the ſtate, however, in which this earth is procurable by ſimply burning the plant, and lixiviating the aſhes, it is conſiderably different, according to the different plants from

1089 Mr Gmelin's experiments.

which it is obtained. The aſhes of mugwort, ſmall centaury, chervil, and dill, are of a browniſh grey; goat's beard and lungwort afford white aſhes; thoſe of ſanicle are whitiſh; thoſe of Roman wormwood of a greeniſh grey; thoſe of rue, agrimony, ſaxiſrage, brown; thoſe of tanſey, of a duſky green; thoſe of dodder, of a fine green; eyebright, ſouthern-wood, common wormwood, and ſcabious, afford them grey; ſcurvy-graſs, of a whitiſh grey; hyſſop, yarrow, and ſowbane, of a duſky grey; melilot, and oak-leaves, as alſo plantain, colts-foot, pine-tops, and fumitory, of a duſky brown; penny-royal, of a pale brown, with ſome ſpots of white; elder-flowers, ſage, and mother of thyme, afford yellow aſhes; thoſe of ſtrawberry-leaves are of a pale brimſtone colour; thoſe of cat-mint, of a duſky red; of prunella, brick-coloured; of honey-ſuckle, blue; of fern, blackiſh; and thoſe of St John's wort, feverfew, origanum, and pimpernel, all of a deep black. The only uſe to which this kind of earth has yet been put, is that of glaſs-making and manure.

Sect. III. *Of Metallic Subſtances.*

§ 1. Gold.

This metal is reckoned of all others the moſt perfect and indeſtructible. When in its greateſt purity, it has very little elaſticity, is not ſonorous, its colour is yellow, it is exceedingly ſoft and flexible, and is more ductile than any other metal whatever. (See Gold *Leaf*, and Wire-Drawing.) Of all bodies it is the moſt ponderous, except platina; its gravity being to that of water, according to Dr Lewis, as 19,280, or 19,290, to one. For its fuſion it requires a low degree of white heat, ſomewhat greater than that in which ſilver melts. Whilſt fluid, it appears of a bluiſh green colour; when cold, its ſurface looks ſmooth, bright, and conſiderably concave: it ſeems to expand more in the act of fuſion, and to ſhrink more in its return to ſolidity, than any of the other metals; whence the greater concavity of its ſurface. Before fuſion it expands the leaſt of all metals, except iron. By ſudden cooling it becomes, as well as other metals, brittle; which effect has been erroneouſly attributed to the contact of fuel during fuſion.

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1090 Unites readily with all the metals.

Gold amalgamates very readily with mercury, and mingles in fuſion with all the metals. It is remarkably diſpoſed to unite with iron; of which it diſſolves many times its own weight, in a heat not much greater than that in which gold itſelf melts; the mixture is of a ſilver colour, very brittle and hard. All the metals, except copper, debaſe the colour of gold; and, if their quantity is nearly equal to that of the gold, almoſt entirely conceal it.

1091 Said to loſe its malleability remarkably with tin.

The malleability of gold is impaired by all the metals, but leſs by copper and ſilver than any others. Tin has had a remarkably bad character in this reſpect; and it has been a received opinion among metallurgiſts, that the ſmalleſt quantity of this metal entirely deſtroys the ductility of gold; and Dr Lewis tells us, that "the moſt minute portion of tin or lead, and even the vapours which riſe from them in the fire, though not ſufficient to add to the gold any weight ſenſible on the tendereſt balance, make it ſo brittle, that it flies to pieces under the hammer." On ſo reſpectable an authority, this continued to be believed as an undoubted fact, until, in the year 1784, a paper appeared in the Philoſophical Tranſactions by Mr Alchorne of the mint: in which it was clearly diſproved by the following experiments:

1092 Mr Alchorne's experiments in oppoſition.

1. Sixty Troy grains of pure tin were put into 12 ounces of pure gold in fuſion; after which the mixture was caſt into a mould of ſand, producing a flat bar an inch wide, and an eighth of an inch thick. The bar appeared ſound and good, ſuffered flatting under the hammer, drawing ſeveral times between a pair of ſteel-rollers, and cutting into circular pieces of near an inch diameter, which bore ſtamping in the money-preſs by the uſual ſtroke, without ſhowing the leaſt brittleneſs, or rather with much the ſame ductility as pure gold.

2. With 90 grains of tin the bar was ſcarce diſtinguiſhable from the former.

3. With 120 grains it was rather paler and harder; and on drawing between the rollers the edges were a little diſpoſed to crack.

4. With 140 grains, the paleneſs, hardneſs, and diſpoſition to crack, were evidently increaſed; nevertheleſs it bore every other operation, even ſtamping under the preſs, without any apparent injury.

5. With an ounce of tin the bar was lead-coloured and brittle, ſplitting into ſeveral pieces on the firſt paſſing between the rollers.

1093 Gold not rendered brittle by the fumes of tin.

6. A ſmall crucible filled with ſtandard gold 11/12 fine, was placed in a larger one, having in it an ounce of melted tin. The whole was covered with a large crucible inverted, in order to direct the fumes of the tin downward upon the gold. The metals were kept in

fuſion

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fuſion for half an hour, during which time a full quarter of the tin was calcined; yet the gold remained altogether unchanged.

7. The mixture of gold and tin produced in exp. 1. was melted a ſecond time in a ſtronger fire than at firſt, and kept in fuſion for half an hour; during which time ſix grains of weight were loſt, but the gold remained equally perfect as before.

1094 Nor by the addition of copper.

8. and 9. The mixtures of exp. 2. and 4. viz. 90 and 140 grains to 12 ounces of gold, were re-melted ſeparately, and an ounce of copper added to each. On being caſt as uſual, they bore all the operations of manufacturing as before, though ſenſibly harder. The laſt cracked at the edges as it had done without the copper, but bore cutting rather better than in its former ſtate.

10. and 11. A quarter of an ounce of the laſt mixture, being tin 140 grains, and copper an ounce, and gold 12 ounces, with as much of the bar from experiment 3. conſiſting of 140 grains of tin to 12 ounces of gold, were each melted by a jeweller in a common ſea-coal fire, into ſmall buttons, without any loſs of weight. Theſe buttons were afterwards forged into ſmall bars, nealing them often with the flame of a lamp, and afterwards drawn each about twenty times through the apertures of a ſteel plate, into fine wire, with as much eaſe as coarſe gold commonly paſſes the like operation.

12. Sixty grains of tin were added to 12 ounces of ſtandard gold $\frac{11}{12}$ fine; and the compound paſſed every one of the operations already deſcribed, without ſhowing the leaſt alteration from the tin.

Several other trials were made with different mixtures of copper, tin, and ſilver, with gold, even as low as two ounces and a half of copper, with half an ounce of tin, to twelve ounces of gold; all of which bore hammering and flatting by rollers to the thinneſs of ſtiff paper, and afterwards working into watch-caſes, cane-heads, &c. with great eaſe. They grew more hard and harſh indeed in proportion to the quantity of alloy; but not one of them had the appearance of what workmen call brittle gold. Mr Alchorne therefore is of opinion, that when brittleneſs has been occaſioned by the addition of tin to gold, the former has been adulterated with arſenic; as he has found, that by adding 12 grains of regulus of arſenic to as many ounces of fine gold, the compound has been rendered altogether unmalleable.

1095 Malleability of gold deſtroyed by regulus of arſenic.

When gold is ſtruck during a certain time by a hammer, or when violently compreſſed, as by the wire-drawers, it becomes more hard, elaſtic, and leſs ductile; ſo that it is apt to be cracked and torn. Its ductility is, however, reſtored by the ſame means uſed with other metals, namely, heating it red hot, and letting it cool ſlowly. This is called *annealing* metals; and gold ſeems to be more affected by this operation than any other metal. The tenacity of the parts of gold is alſo very ſurpriſing; for a wire of $\frac{1}{10}$ of an inch in diameter will ſupport a weight of 500 pounds.

1096 Surpriſing tenacity of its parts.

1097 Not liable to ruſt.

Gold is unalterable by air or water. It never contracts ruſt like other metals. The action of the fierceſt furnace-fires occaſions no alteration in it. Kunckel kept gold in a glaſs-houſe furnace for a month, and Boyle kept ſome expoſed to a great heat for a ſtill longer time, without the loſs of a ſingle grain. It is ſaid, however, to be diſſipable in the focus of a large burning mirror.

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1098 Mr Boyle's experiments for the deſtructibility of gold.

Mr Boyle relates a very curious and extraordinary experiment, which he thought was ſufficient to prove the total deſtructibility of gold. About an eighth part of a grain of powder, communicated by a ſtranger, was projected upon two drachms of fine gold in fuſion, and the matter kept melted for a quarter of an hour. During the fuſion, it looked like ordinary gold; except only once, that his aſſiſtant obſerved it to look exactly of the colour of opal. When cold, it was of a dirty colour, and, as it were, overcaſt with a thin coat, almoſt like half-vitrified litharge: the bottom of the crucible was overlaid with a vitrified ſubſtance, partly yellow, and partly reddiſh brown; with a few ſmall globules, more like impure ſilver than gold. The metal was brittle, internally like braſs or bell-metal; on the touchſtone more like ſilver than gold: its ſpecific gravity was to that of water only as $15\frac{2}{5}$ to 1. There was no abſolute loſs of weight. By cupellation, 60 grains of this maſs yielded 53 grains of pure gold, with ſeven grains of a ponderous, fixed, dark-coloured ſubſtance.

1099 Solution in aqua-regia.

We have already mentioned, that in certain circumſtances gold is ſoluble in the nitrous and marine acids ſeparately. It is, however, always ſoluble by the two united, but diſſolves ſlowly even then. The moſt commodious method of obtaining this ſolution is, by putting the gold, either in leaves, or granulated, or cut into ſmall thin pieces, into a proper quantity of aquafortis; then adding, by degrees, ſome powdered ſal ammoniac, till the whole of the gold is diſſolved. By this means a much ſmaller quantity of the menſtruum proves ſufficient, than if the ſal ammoniac was previouſly diſſolved in the aquafortis; the conflict, which each addition of the ſalt raiſes with the acid, greatly promoting the diſſolution. Aquafortis of moderate ſtrength will, in this way, take up about one-third of its weight of gold; whereas an aqua-regis, ready prepared from the ſame aquafortis, will not take up above one-fifth its weight. Common ſalt anſwers better for the preparation of the aqua-regis than ſal ammoniac.

1100 Properties of the ſolution.

This ſolution, like all other metallic ones, is corroſive. It gives a violet colour to the fingers, or to any animal matters. If the ſolution is evaporated and cooled, yellow tranſparent cryſtals will be formed: but, if the evaporation is carried too far, the acids with which the gold is combined may be driven from it by heat alone; and the gold will be left in the ſtate of a yellow powder, called *calx of gold*.

1101 Gold precipitated from it.

Gold may be precipitated from its ſolution by thoſe ſubſtances which commonly precipitate metals, ſuch as alkaline ſalts and calcareous earths. It may alſo be precipitated in a fine purple powder, by tin or its ſolution.

When fixed alkalies are made uſe of, the precipitate weighs about one-fourth more than the gold employed. With volatile alkalies alſo, if they are added in no greater proportion than is ſufficient to ſaturate the acid, the quantity of precipitate proves nearly the ſame: but if volatile ſpirit is added in an over-proportion, it rediſſolves part of the gold which it had before precipitated, and the liquor becomes again conſiderably yellow. The whole of the precipitate, however,

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ever, could not be rediſſolved, either by the mild or cauſtic alkali; nor did either of theſe ſpirits ſenſibly diſſolve or extract any tinge from precipitates of gold which had been thoroughly edulcorated with boiling water.

1102 Separated from other metals by vitriol of iron.

All the metallic bodies which diſſolve in aqua-regia, precipitate gold from it. Mercury and copper throw down the gold in its bright metalline form; the others, in that of a calx or powder, which has no metallic aſpect. Vitriol of iron, though it precipitates gold, yet has no effect upon any other metal; hence it affords an eaſy method of ſeparating gold from all other metals. The precipitation with tin ſucceeds certainly only when the metal in ſubſtance is uſed, and the ſolution of gold largely diluted with water. It is obſervable, that though the gold is precipitated from the diluted ſolution by tin, yet, if the whole is ſuffered to ſtand till the water has in a great meaſure exhaled, the gold is taken up afreſh, and only a white calx of tin remains.

1103 Aurum fulminans.

1104 Known in the 15th century.

1105 Baſil Valentine's directions for its preparation.

Gold precipitated from its ſolution in aqua-regia explodes by heat with much greater violence than any other ſubſtance in nature. This property was known in the 15th century; but whether the ancient alchemiſts knew any thing of it or not, is a matter of uncertainty. Baſil Valentine firſt gave any diſtinct account of it. He directs the gold to be diſſolved in aqua-regia made with ſal ammoniac, and then precipitated by vegetable fixed alkali, to be twelve times waſhed with water, and laſtly dried in the open air, where the ſun's rays cannot reach it. He forbids it to be dried over a fire, as it explodes with a gentle heat, and flies off with inconceivable violence.

Succeeding chemiſts have performed this operation with ſome little differences; but the neceſſity of employing volatile alkali was but little regarded till the beginning of the preſent century.

1106 Uſe of volatile alkali but lately known.

1107 Increaſe of the weight of gold by being changed into aurum fulminans.

1108 Prodigious force with which it explodes.

The calx of gold is always ſomewhat increaſed in weight by being converted into aurum fulminans; but authors are not agreed about the quantity of augmentation. Becher makes it heavier by one-fifth part; Lemery by one-fourth; and Juncker by one-fourth. All agree, however, that it explodes with a violence almoſt inconceivable. Crollius relates, that 20 grains of this powder explodes with more force than half a pound of gun powder, and exerts its force downwards, though M. Teykmeyer frequently ſhowed in his lectures that it would throw a florin upwards above ſix ells. A great number of experiments were made before the Royal Society at London, in order to determine the comparative forces of theſe two powders. Equal parts of gunpowder and aurum fulminans were included in iron globes placed among burning coals; thoſe which contained the former burſt with great violence, but the globes containing the aurum fulminans remained perfectly ſilent.

1109 Does not explode in cloſe veſſels.

But though no exploſion takes place in cloſe veſſels, the utmoſt caution is neceſſary in managing this ſubſtance in the open air; eſpecially when it is ſubjected to friction, or to a ſlight degree of heat; for ſuch is the nature of the calx we ſpeak of, that it is not neceſſary, in order to cauſe it explode, to touch it with an ignited ſubſtance, or to make it red-hot.

1110 Heat requiſite for the exploſion.

The heat requiſite for this purpoſe is, according to Dr Lewis, intermediate between that of boiling water and the heat which makes metals of an obſcure red.

1111 Explodes readily by friction.

With friction, however, it ſeems ſtill more dangerous; for in this caſe it explodes with what we ſhould think ſcarce ſufficient to communicate any degree of heat whatever. Orſchal relates, that this powder ground in a jaſper mortar, exploded with ſuch violence as to burſt the veſſel in a thouſand pieces;

1112 Inſtances of its miſchievous effects.

Dr Lewis gives an inſtance of a ſimilar kind in England; and Dr Birch tells us of doors and widows torn to pieces by the violence of this exploſive matter. Mr Macquer relates the following accident to which he was witneſs. "A young man, who worked in a laboratory, had put a drachm of fulminating gold into a bottle, and had neglected to wipe the inner ſurface of the neck of the bottle, to which ſome of the powder adhered. When he endeavoured to cloſe the bottle, by turning round the glaſs ſtopper, the friction occaſioned an exploſion of part of the powder. By this the young man was thrown ſome ſteps backward, his face and hands wounded by the fragments of the bottle, and his eyes put out; yet, notwithſtanding this violent exploſion, the whole drachm of fulminating gold certainly did not take fire as much of it was afterwards found ſcattered about the laboratory."

1113 Force of the exploſion is not directed entirely downwards.

It has already been mentioned, that ſome imagine the force of this exploſion to be directed downwards; but Dr Lewis is of opinion that it is equally directed every way. Certain it is, that the quantity of from 10 to 12 grains of aurum fulminans, exploded on a metalline plate, lacerates it; a ſmaller quantity forms a cavity, and a ſtill ſmaller only ſcratches the ſurface; effects which are never produced by gunpowder in ever ſo large a quantity. A weight laid upon the powder is thrown upwards in the moment of exploſion. If it be of ſilver or copper, this weight is marked with a yellowiſh ſpot, as the ſupports will alſo be, if made of either of theſe metals. A large grain, ſays Mr Bergman, brought near to the ſide of the flame of a candle, blows it out with great noiſe; and a few ounces exploding together by incautious drying, has been known to ſhatter the doors and windows of the apartment: hence it is evident, that aurum fulminans exerts its force in all directions; yet it cannot be denied, that it ſtrikes bodies with which it is in contact more violently than thoſe which are at a ſmall diſtance, though in its vicinity: thus, if a ſmall portion of it explodes in a paper box, it lacerates only the bottom, unleſs the top be preſſed down cloſe, in which caſe it perforates both the top and bottom. When carefully and gradually exploded in a glaſs phial or a paper box, it leaves a purple ſoot, in which are found many particles of ſhining gold; and if the quantity exploded be large, ſeveral grains remain totally unchanged, as it is only the lowermoſt ſtratum that is inflamed.

1114 Exploſion of moiſt aurum fulminans.

Aurum fulminans, when moiſt, does not explode at all: but as it dries, the grains go off in ſucceſſion like the decrepitation of common ſalt.—In glaſs veſſels cloſed, or with their mouths immerſed in water, it explodes, but with a very weak report. An elaſtic vapour, in the quantity of ſeven inches, from half a drachm of the powder, broke forth in the moment of exploſion, which, by our author's account, ſeems to be phlogiſticated air. In metallic veſſels ſufficiently ſtrong, the gold is ſilently reduced when they are perfectly

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fectly ſound; but if they have any very ſmall chinks in them, the vapour makes its way through them with a hiſſing noiſe.

1115 Cauſe of this exploſion attributed to a ſaline principle.

The cauſe of this extraordinary exploſive force of gold has been attributed chiefly to a ſaline principle, *viz.* The combination of nitrous acid with volatile alkali; and this opinion has been ſupported by an aſſertion, that the fulminating property is deſtroyed by treating the calx with vitriolic acid or with fixed alkali; the former expelling the nitrous acid, and the latter diſengaging the volatile alkali. Mr Bergman allows that fixed alkali deſtroys the fulminating property; but affirms, that it acts only by ſeparating the particles when the two are triturated together; and this might be done by many other ſubſtances as well as fixed alkali: But when the alkali, inſtead of being triturated in the dry way with the calx, was boiled in water along with it, the exploſion not only took place, but was much more violent than uſual. It muſt be obſerved, however, that heat alone deſtroys the fulminating property of this calx; and therefore, if the alkaline ſolution be made too ſtrong, the additional heat which it then becomes capable of ſuſtaining, is ſufficient to deprive the calx of its fulminating property. The caſe is the ſame with the vitriolic acid; for this has no effect upon the calx, either by digeſtion in its concentrated ſtate, or by boiling in its diluted ſtate. If it be boiled in its concentrated ſtate indeed with the fulminating calx, the heat conceived by the acid is ſufficient to deſtroy the fulminating property of the former; and in like manner, unleſs the calx be in ſome meaſure deſtroyed, or reduced to its metallic ſtate, it can never be deprived of its fulminating property.

1116 This opinion ſhown to be erroneous by Mr Bergman.

1117 Aurum fulminans can be made without nitrous or marine acids.

It was further proved, that the fulminating property did not depend on the preſence either of nitrous or marine acids, for it can be made without them. A calx of gold, not fulminating, diſſolved in vitriolic acid, and precipitated by cauſtic volatile alkali, had acquired this property. A ſolution of the ſame calx in nitrous acid, let fall a precipitate by the addition of pure water; and this precipitate edulcorated, and digeſted with volatile alkali, fulminated as if it had been originally precipitated with that alkali. The experiment was repeated on the other non-fulminating precipitates with the ſame ſucceſs. Leſt any ſuſpicion, however, ſhould remain, that a ſmall quantity of aqua-regia might ſtill be left, which, by combining with the volatile alkali, would make a proportionable quantity of nitrum flammans, the precipitate was digeſted 24 hours in vitriolic acid, then waſhed in pure water, and immerſed in aqueous and ſpirituous ſolutions of alkali, both mild and cauſtic; but the event was the ſame. Laſtly, an inert calx of gold may always be made to fulminate by digeſting it with volatile alkali; nor can this property be communicated to it by any means without the uſe of this alkali.

1118 Fixed air not the cauſe of the exploſion.

It has been ſuppoſed by ſome very eminent chemiſts, among whom we may number Dr Black, that fixed air is the cauſe of the fulmination of gold: but it is evident that this cannot be the caſe: becauſe, 1. Gold fulminates as well when precipitated by the cauſtic volatile alkali, as by that which contains fixed air, 2. This metal does not combine, during precipitation, with fixed air. 3. Gold, when precipitated by mild fixed alkali, does not fulminate, unleſs the menſtruum contain volatile alkali.

The fulminating calx of gold may be prepared either with the compound aqua-regia of pure nitrous and marine acids; of pure nitrous acid and ſal ammoniac; or of a compound of alum, nitre, and ſea-ſalt. When this kind of liquor is made uſe of, the acid of the alum expels the other two, and thus forms an aqua-regia. This was formerly called *menſtruum ſine ſtrepitu.* By whatever method the gold is diſſolved, it always affords a yellow calx with alkalies, but the volatile alkali moſt readily throws down the metal. Dephlogiſticated ſpirit of ſalt very readily diſſolves gold, and produces a fulminating precipitate as well as aqua-regia.

1119 Menſtruum ſine ſtrepitu.

1120 Mr Bergman's theory of the cauſe of the exploſion.

We ſhall conclude this account of aurum fulminans with an abſtract of Mr Bergman's theory of the exploſion.—He obſerves, that volatile alkali contains phlogiſton; an undoubted proof of which is given by Dr Prieſtley, by coverting alkaline into phlogiſticated air. This phlogiſton, ſays he, may be ſeparated by means of a ſuperior attraction; ſo that the volatile alkali is decompoſed, and the reſiduum diſſipated in form of an elaſtic fluid, altogether ſimilar to that which is extricated during the fulmination: the ſource then from whence the elaſtic fluid is derived muſt be obvious; and it only remains to examine the medium by which the volatile alkali is dephlogiſticated.

'In thoſe metals which are called *perfect*, ſo great is the firmneſs of texture, and ſo cloſe the connection of the earthy principle with the phlogiſton, that by means of fire alone theſe principles cannot be diſunited: but when diſſolved by acid menſtrua, they muſt neceſſarily loſe a portion of their phlogiſton; and therefore, when afterwards precipitated by alkalies which cannot ſupply the loſs, they fall down in a calcined ſtate, though they attract phlogiſton ſo ſtrongly, that they can be reduced to a metallic ſtate, merely by an intenſe heat penetrating the veſſels. It may therefore be laid down as a fundamental poſition, that gold is calcined by ſolution.

1121 Volatile alkali the cauſe of the exploſion.

"Let us now conſider the conſequence of expoſing the powder conſiſting of calx of gold and volatile alkali intimately united, to an heat gradually increaſed. The calx which is united with the volatile alkali, by the aſſiſtance of a gentle heat, ſeizes its phlogiſton; and when this is taken away, the reſiduum of the ſalt is inſtantaneouſly expanded into the form of an elaſtic fluid, which is performed with ſo much violence, that the air muſt yield a very acute ſound."

1122 Volatile alkali exhibits a flaſh when thrown into a hot crucible.

Our author proceeds to explain this phenomenon upon the principles aſſumed by him and Mr Scheele, of heat being a compoſition of light, and the phlogiſton or principle of inflammability; but as this hypotheſis is by no means ſatisfactory, we ſhall omit his reaſoning founded upon it: That the volatile alkali, however, is really capable of producing a flaſh is eaſily proved, becauſe it exhibits one when thrown into a hot crucible. A ſingle cubic inch of gun-powder generates about 244 of elaſtic fluid; but the ſame quantity of aurum fulminans yields at leaſt four times as much; and hence we may eaſily underſtand the difference in their exploſive force.

1123 Great quantity of elaſtic fluid produced by aurum fulminans.

"That careful calcinations ſhould deſtroy the fulmi-

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minating property, is not to be wondered at, as the volatile alkali is the indispensible material cause; but, the peculiar alacrity which it acquires before the explosive force is totally extinguished, depends upon the nature of the materials, and of the operation. Thus the heat, when inferior to that necessary for fulmination, acts upon both the principles of the aurum fulminans, it prepares the metallic calx for a more violent attraction for phlogiston; it also acts upon the phlogiston of the volatile alkali, and lessens its connection; which two circumstances must tend to the union producing the explosion. But this effect has a maximum; and at this period the slightest friction supplies the defect of necessary heat, and produces the fulmination. The calcined gold also seems to collect and fix the matter of heat, though still insufficient by means of its phlogiston, in a certain degree; so that by means of friction, though but very slight, it becomes capable of exerting its force; but when the heating is often repeated without procuring its effect, the volatile alkali is by degrees dissipated, and at length so much diminished that the calx becomes inert.

1124 Why slight calcination destroys the fulminating property.

1125 Why it will not explode in close vessels.

"But if aurum fulminans is capable of producing such a prodigious quantity of elastic fluid, how does it happen that it remains mute and inert when reduced in close vessels? Of this the reason may be, that every elastic fluid, in the act of breaking forth, requires a space to expand in; and if this be wanting, it remains fixed. Taking this for granted, a calx of gold cannot be reduced in close vessels either by heat or by the phlogiston of volatile alkali; for in either case it must evolve its elastic fluid, which by supposition it cannot do. Nothing remains to solve this difficulty but the ignition of the surrounding metal; by means of which the calx, in virtue of its superior attraction, seizes the phlogiston of the metal, which that substance here, as well as in other instances, is capable of losing without the eruption or absorption of any fluid whatever."

1126 Mr Bergman's opinions of the fublimation of other calces.

Several chemists have asserted, that the calces of copper or silver may be made to fulminate like that of gold. But Mr Bergman informs us, that these experiments never succeeded with him; "so (says he) they have either been silent upon some circumstances necessary in the operation, or perhaps have been deceived by the detonation of nitrum flammans, or some other accidental occurrence. It is not sufficient for the volatile alkali to adhere to the precipitate; for platina thrown down by this alkali retains a portion of it very obstinately, but yet does not fulminate on the exposure of fire.—Besides the presence of volatile alkali, it seems to be necessary that the metallic calx should be reducible by a gentle heat, in order to decompose it; but every explosion is not to be derived from the same causes; nay, in this respect, aurum fulminans, gun-powder, and pulvis fulminans, differ very much, though they agree in several particulars." Of late, however, it has been found that the calx of silver may be made to fulminate in a manner still more extraordinary than that of gold. See the next article.

1127 Solution of gold by hepar sulphuris.

If gold is melted with an hepar sulphuris, composed of equal parts of sulphur and fixed alkaline salt, the metal readily unites with it into an uniform mass, capable of dissolution in water without any separation of its parts. The solution, besides a nauseous taste from the sulphur, has a peculiar penetrating bitterness, not discoverable in any other metalline solution made by the same means.

Though the compositions of sulphur and alkali seem to unite more intimately with gold than any other metal, their affinity with it is but slight; copper, or iron, added to the matter in fusion, disunite, and precipitate the gold. The metal thus recovered, and purified by the common processes, proves remarkably paler-coloured than at first. In an experiment related by Dr Brandt, in the Swedish Memoirs, the purified gold turned out nearly as pale as silver, without any diminution of weight.

1128 Medicinal virtues of gold.

Gold has been thought to be possessed of many extraordinary virtues as a medicine; which, however, are long ago determined to be only imaginary. It is not indeed very easy to prepare this metal in such a manner that it can be safely taken into the human body. The solution in aqua-regia is poisonous; but if any essential oil is poured on this solution, the gold will be separated from the acid, and united to the essential oil; with which, however, it contracts no lasting union, but in a few hours separates in bright yellow film to the sides of the glass. Vitriolic ether dissolves the gold more readily and perfectly than the common essential oils; and keeps it permanently suspended, the acid liquor underneath appearing colourless. The yellow ethereal solution poured off, and kept for some time in a glass stopt with a cork, so that the spirit may slowly exhale, yields long, transparent, prismatic crystals, in shape like those of nitre, and yellow like topaz. What the nature of these crystals is, either as to medicinal effects, or other purposes, is as yet unknown.

1129 Etheral solution.

Rectified spirit of wine mingles uniformly with the solution of gold made in acids: if the mixture is suffered to stand for some days in a glass slightly covered, the gold is by degrees revived, and arises in bright pellicles to the surface. Grosser inflammable matters, wine, vinegar, solutions of tartar, throw down the gold, in its metallic form, to the bottom. Gold is the only metal which is thus separable from its solution in acids by these substances; and hence gold may be purified by these means from all admixtures, and small proportions of it in liquors readily discovered.

1130 Colour of gold restored.

When the colour of gold is by any means rendered pale, it may be recovered again by melting it with copper, and afterwards separating the copper; or by a mixture of verdigris and sal ammoniac with vitriol or nitre. The colour is also improved by fusion with nitre, injecting sal ammoniac upon it in the fusion, quenching it in urine, or boiling it in a solution of alum. When borax is used as a flux, it is customary to add a little nitre or sal ammoniac, to prevent its being made pale by the borax. Juncker reports, that by melting gold with four times its weight of copper, separating the copper by aquafortis unpurified, then melting the gold with the same quantity of fresh copper, and repeating this process eight or nine times, the gold becomes at length of a deep red colour, which sustains the action of lead, antimony, and aquafortis.

§ 2.

Silver.

§. 2. *Silver.*

1131 Ductility of ſilver.

THIS, next to gold, is the moſt perfect, fixed, and ductile of all the metals. Its ſpecific gravity is to that of water nearly as 11 to 1. A ſingle grain has been drawn into a wire three yards long, and flatted into a plate an inch broad. In common fire it ſuffers no diminution of its weight; and, kept in the vehement heat of a glaſs-houſe for a month, it loſes no more than one ſixty-fourth. In the focus of a large burning-glaſs, it ſmokes for a long while, then contracts a greyiſh aſh on the ſurface, and at length is totally diſſipated.

Silver is ſomewhat harder and more ſonorous than gold, and is fuſible with a leſs degree of heat. The tenacity of its parts alſo is nearly one half leſs than that of gold; a ſilver wire of $\frac{1}{10}$ of an inch diameter being unable to bear more than 270 pounds.

1132 Effects of ſulphur on it.

Mercury unites very readily with ſilver-leaf, or with the calx of ſilver precipitated by copper; but does not touch the calces precipitated by alkaline ſalts. The vapours of ſulphureous ſolutions ſtain ſilver yellow or black. Sulphur, melted with ſilver, debaſes its colour to a leaden hue, renders it more eaſily fuſible than before, and makes it flow ſo thin as to be apt in a little time to penetrate the crucible: in a heat juſt below fuſion, a part of the ſilver ſhoots up, all over the ſurface, into capillary effloreſcence. Aquafortis does not act upon ſilver in this compound; but fixed alkaline ſalts will abſorb the ſulphur, and from a hepar ſulphuris, which, however, is capable of again diſſolving the metal. If the ſulphurated ſilver is mixed with mercury ſublimate, and expoſed to the fire, the mercury of the ſublimate will unite with the ſulphur, and carry it up in the form of cinnabar, whilſt the marine acid of the ſublimate unites with the ſilver into a luna cornea, which remains at the bottom of the glaſs. Fire alone is ſufficient, if continued for ſome time, to expel the ſulphur from ſilver.

1133 Purification.

From the baſer metals, ſilver is purified by cupellation with lead. (See REFINING.) It always retains, however, after that operation, ſome ſmall portion of copper, ſufficient to give a blue colour to volatile ſpirits, which has been erroneouſly thought to proceed from the ſilver itſelf. It is purified from this admixture by melting it twice or thrice with nitre and borax. The ſcoria, on the firſt fuſion, is commonly blue; on the ſecond, green; and on the third, white, which is a mark of the purification being completed.

1134 Luna cornea reduced.

The moſt effectual means, however, of purifying ſilver, is by reviving it from luna cornea; becauſe ſpirit of ſalt will not precipitate copper as it does ſilver. The ſilver may be recovered from luna cornea, by fuſion with alkaline and inflammable fluxes; but, in theſe operations, ſome loſs is always occaſioned by the diſſipation of part of the volatile calx, before the alkali or metal can abſorb its acid.

1135 Mr Margraaf's method.

Mr Margraaf has diſcovered a method of recovering the ſilver with little or no loſs; mercury aſſiſted by volatile ſalts, imbibing it by trituration without heat. One part of luna cornea, and two of volatile ſalt, are to be ground together in a glaſs-mortar, with ſo much water as will reduce them to the conſiſtence of a thin paſte, for a quarter of an hour, or more; five parts of pure quickſilver are then to be added, with a little more water, and the triture to be continued for ſome hours. A fine amalgam will thus be obtained; which is to be waſhed with freſh parcels of water, as long as any white powder ſeparates. Nearly the whole of the ſilver is contained in the amalgam, and may be obtained perfectly pure by diſtilling off the mercury. The white powder holds a ſmall proportion ſeparable by gentle ſublimation; the matter which ſublimes is nearly ſimilar to mercurius dulcis.

The colour of ſilver is debaſed by all the metals, and its malleability greatly injured by all but gold and copper. The Engliſh ſtandard ſilver contains one part of copper to twelve and one-third of pure ſilver. This metal diſcovers in ſome circumſtances a great attraction for lead; though it does not retain any of that metal in cupellation. If a mixture of ſilver and copper be melted with lead in certain proportions, and the compound afterwards expoſed to a moderate fire, the lead and ſilver will melt out together, bringing very little of the copper with them; by this means ſilver is often ſeparated from copper in large works. The effect does not wholly depend upon the different fuſibility of the metals; for if tin, which is ſtill more fuſible than lead, be treated in the ſame manner with a mixture of ſilver and copper, the three ingredients are found to attract one another ſo ſtrongly as to come all into fuſion together. Again, if ſilver be melted with iron, and lead added to the mixture, the ſilver will forſake the iron to unite with the lead, and the iron will float by itſelf on the ſurface. 1136 Attraction for lead.

Silver is purified and whitened externally by boiling in a ſolution of tartar and common ſalt. This is no other than an extraction of the cupreous particles from the ſurface of the ſilver, by the acid of the tartar acuated by the common ſalt. 1137 Whitened externally.

M. Bertholle t has lately diſcovered a method of imparting to the calx of ſilver a fulminating property, and that much more terrible than fulminating gold itſelf. His receipt for making it is, "Take cupelled ſilver, and diſſolve it in the nitrous acid; precipitate the ſilver from the ſolution by lime-water, decant the clear liquor, and expoſe the precipitate three days to the open air. Mix this dried precipitate with the cauſtic volatile alkali, it will turn black; and when dried in the air, after decanting the clear liquor, is the fulminating powder required." 1138 Fulminating ſilver. 1139 How prepared.

The properties of this powder are ſaid to be ſo extraordinary, that it is impoſſible to imagine how any part of it can ever be ſeparated from the reſt after it is once prepared. To make this fulminate, it ſeems no ſenſible degree of heat is neceſſary, the contact of a cold body anſwering that purpoſe as well as any other. After it is once made, therefore, it muſt not be touched, but remain in the veſſel in which it is dried; and ſo violent is the exploſion, that it is dangerous to attempt it in larger quantities than a grain at a time. For the ſame reaſon it undoubtedly follows, that no more than a grain ought to be made at a time, or at leaſt in one veſſel, becauſe no part of it could ever afterwards be ſeparated from the reſt. We are told, that, "the wind having turned over a paper containing ſome atoms of this powder," (we ought to have been 1140 Fulminates by the touch of any ſubſtance whether cold or hot. 1141 Dangerous when more than a grain is fulminated at a time.

Silver. been informed how the atoms came there, considering what we have just now related,) "the portion touched by the hand fulminated, and of course that which fell upon the ground. A drop of water which fell upon this powder caused it to fulminate. A single grain of fulminating silver, which was in a glass cup, reduced the glass to powder, and pierced several doubles of paper.

1142 Fulminating crystals. "If the volatile alkali, which has been employed with the above powder, be put into a thin glass matrass and boiled, then, on standing in the cold, small crystals will be found sublimed on the interior sides of the vessel, and covering the liquor. On touching one of these crystals the matrass will be burst with considerable explosion.

1143 Cautions to be used in preparing it. "The dangerous properties of this powder suggest the necessity of not preparing it but when the face is covered with a mask with glass eyes; and to avoid the rupture of the glass cups, it is prudent to dry the fulminating silver in small metalline vessels." To this we may add, that as the powder does not fulminate when wet, it may in that state be put up in very small quantities on paper, to be fulminated afterwards as occasion offers. This will perhaps account for the appearance of the few atoms abovementioned on the paper which the wind overturned.

1144 Absurd theory of the antiphlogistons. With regard to the cause of this extraordinary fulmination we can say nothing satisfactory; the following curious reason is assigned by the antiphlogistons; which at once shows the futility of their theory, and sets in a very ridiculous light the hard words with which they would obscure the science of chemistry. "The oxygenous principle* (say they) unites with the hydrogenous principle † of the volatile alkali, and form water in a vaporous state. This water (in a vaporous state) being instantaneously *thrown into a state of vapour*, possessing elasticity and expansive force, is the principal cause of this phenomenon, in which the *azotic* ‡ air which is disengaged from the volatile alkali, with its whole expansile power, has a great share."

* Dephlogisticated air.
† Inflammable air.
‡ Phlogisticated air.

1145 Remarks on this and other theories. On this, as well as other theories, in which elastic fluids are alleged to be the cause of explosions, it is obvious to remark, that should we allow this to be the case, we are utterly at a loss to find a source of heat sufficient to rarefy the vapour to such a degree as is necessary for producing the effect ascribed to it. In the present case, we can scarce suppose a grain weight of metalline calx, already dry, to contain as much either of fire or water as is necessary to produce the effect; nor can we explain why the touch of any cold body, and which may be supposed to contain less fire than the calx itself, should produce such an effect. As to the oxygenous and hydrogenous principles, they were there before the touch, and ought to have produced their effects, not to mention that the water produced

1146 The phenomenon probably owing to electricity. by them could not have amounted to the thousandth part of a grain. It is much more probable, therefore, that the whole is to be considered as an effect of electricity, though we cannot tell how the fluid comes here to be excited in such a violent manner.

§ 3. *Copper.*

This is one of those metals which, from their destructibility by fire, and contracting rust in the air, are called *imperfect*. Of these, however, it is the most perfect and indestructible. It is of a reddish colour when pure; easily tarnishes in a moist air, and contracts a green rust. It is the most sonorous of all the metals, and the hardest and most elastic of all but iron. In some of its states, copper is as difficultly extended under the hammer as iron, but always proves softer to the file; and is never found hard enough to strike a spark with flint or other stones; whence its use for chissels, hammers, hoops, *&c.* in the gunpowder works. When broke by often bending backwards and forwards, it appears internally of a dull red colour without any brightness, and of a fine granulated texture resembling some kinds of earthen ware. It is considerably ductile, though less so than either gold or silver; and may be drawn into wire as fine as hair, or beaten into leaves almost as thin as those of silver. The tenacity of its parts is very considerable; for a copper wire of $\frac{1}{10}$ of an inch diameter will support a weight of $299\frac{1}{4}$ pounds without breaking. The specific gravity of this metal, according to Dr Lewis, is to that of water as 8.830 to 1.

Copper. 1147 Always softer than iron.

Copper continues malleable when heated red; in which respect it agrees with iron; but is not, like iron, capable of being welded, or having two pieces joined into one. It requires for its fusion a stronger heat than either gold or silver, though less than that requisite to melt iron. When in fusion, it is remarkably impatient of moisture; the contact of a little water occasioning the melted copper to be thrown about with violence, to the great danger of the by-standers. It is, nevertheless, said to be granulated in the brass-works at Bristol, without explosion or danger, by letting it fall in little drops, into a large cistern of cold water covered with a brass-plate. In the middle of the plate is an aperture, in which is secured with Sturbridge clay a small vessel, whose capacity is not above a spoonful, perforated with a number of minute holes, through which the melted copper passes. A stream of cold water passes through the cistern. If suffered to grow hot, the copper falls liquid to the bottom, and runs into plates.

1148 How granulated.

Copper, in fusion, appears of a bluish green colour, nearly like that of melted gold. Kept in fusion for a long time, it becomes gradually more and more brittle; but does not scorify considerably, nor lose much of its weight. It is much less destructible than any of the imperfect metals, being very difficultly subdued even by lead or bismuth. If kept in a heat below fusion, it contracts on the surface thin powdery scales; which, being rubbed off, are succeeded by others, till the whole quantity of the metal is thus changed into a scoria or calx, of a dark reddish colour. This calx does not melt in the strongest furnace fires; but, in the focus of a large burning mirror, runs easily into a deep red, and almost opaque, glass. A flaming fire, and strong draught of air over the surface of the metal, greatly promote its calcination. The flame being tinged of a green, bluish, or rainbow colour, is a mark that the copper burns.

1149 Calcined.

This metal is very readily soluble by almost all saline substances; even common water, suffered to stand long in copper vessels, extracts so much as to gain a coppery taste. It is observable, that water is much more impregnated with this taste, on being suffered to stand in the cold, than if boiled for a longer time in the vessel. The same thing happens in regard to the mild vegetable acids. The confectioners prepare the most acid syrups, even those of lemons and oranges, by

1150 Solubility.

Copper. by boiling in clean copper-vessels, without the preparations receiving any ill taste from the metal; whereas, either the juices themselves, or the syrups made from them, if kept cold in copper vessels, soon become impregnated with a disagreeable taste, and with the pernicious qualities of the copper.

1151 Altered by combination with vegetable acids. By combination with vegetable acids, copper becomes in some respects remarkably altered. Verdigris, which is a combination of copper with a kind of acetous or tartareous acid, is partially soluble in distilled vinegar; the residuum, on being melted with borax and linseed oil, yields a brittle metallic substance, of a whitish colour, not unlike bell-metal. The copper also, when revived from the distilled verdigris, was found by Dr Lewis to be different from the metal before dissolution; but neither of these changes have yet been sufficiently examined.

1152 Amalgamation with mercury. Copper, in its metallic state, is very difficultly amalgamated with mercury; but unites with it more easily if divided by certain admixtures. If mercury and verdigris be triturated together with common salt, vinegar, and water, the copper in the verdigris will be imbibed by the mercury, and form with it, as Boyle observes, a curious amalgam, at first so soft as to receive any impression, and which, on standing, becomes hard like brittle metals. Brass leaf likewise gives out its copper to mercury, the other ingredient of the brass separating in the form of powder.

1153 Dr Lewis's method. Easier methods of amalgamating copper are published by Dr Lewis in his notes on Wilson's Chemistry, p. 432. His receipts are,—"Dissolve some fine copper in aquafortis: when the menstruum will take up no more of the metal, pour it into an iron mortar, and add six times the weight of the copper, of mercury, and a little common salt: grind the whole well together with an iron pestle; and, in a little time, the copper will be imbibed by the mercury, and an amalgam formed, which may be rendered bright by washing it well with repeated affusions of water.

"*Another method.* Take the muddy substance which is procured in the polishing of copper plates with a pumice stone, and grind it well with a suitable portion of mercury, a little common salt, and some vinegar, in an iron mortar, (a marble one will do, if you make use of an iron pestle), till you perceive the mercury has taken up the copper." The copper recovered from these amalgams retains its original colour, without any tendency to yellow. Even when brass is made use of for making the amalgam, the recovered metal is perfect red copper; the ingredient from which the brass received its yellowness being, as above observed, separated in the amalgamation.

1154 Brass, how prepared. Copper is the basis of several metals for mechanic uses; as brass, prince's metal, bell-metal, bath-metal, white copper, &c. Brass is prepared from copper and calamine, with the addition of powdered charcoal, cemented together, and at last brought into fusion. The calamine is to be previously prepared by cleansing it from adhering earth, stone, or other matters; by roasting, or calcining it; and by grinding it into a fine powder. The length of time, and degree of heat, requisite for the calcination of the calamine, are different according to the qualities of that mineral. The calamine, thus calcined, cleansed, and ground, is to be mixed with about a third or fourth part of charcoal dust, or powdered pit-coal, as is done in some parts of England. The malleability of the basis is diminished by the use of pit-coal, which is therefore only employed for the preparation of the coarser kinds. To this composition of calamine and coal, some manufacturers add common salt, by which the process of making brass is said to be hastened. In Goslar, where the cadmia adhering to the insides of the furnaces is used instead of the native calamine, a small quantity of alum is added, by which they pretend the colour of the brass is heightened. With this composition, and with thin plates or grains of copper, the crucibles are to be nearly filled. The proportion of the calamine to the copper varies according to the richness of the former, but is generally as three to two. The copper must be dispersed through the composition of calamine and coal; and the whole must be covered with more coal, till the crucibles are full. The crucibles, thus filled, are to be placed in a furnace sunk in the ground, the form of which is that of the frustum of a hollow cone. At the bottom of the furnace, or greater basis of the frustum, is a circular grate, or iron-plate. This plate is covered with a coat of clay and horse-dung, to defend it from the action of the fire; and pierced with holes, through which the air maintaining the fire passes. The crucibles stand upon the circular plate, forming a circular row, with one in the middle. The fuel is placed betwixt the crucibles, and is thrown into the furnace at the upper part of it, or the lesser basis of the frustum. To this upper part or mouth of the furnace is fitted a cover made of bricks or clay, kept together with bars of iron, and pierced with holes. This cover serves as a register. When the heat is to be increased, the cover must be partly or entirely taken off, and a free draught is permitted to the external air, which passes along a vault under-ground to the ash-hole, through the holes in the circular grate or plate, betwixt the crucibles, and through the upper mouth, along with the smoke and flame, into an area where the workmen stand, which is covered with a large dome or chimney, through which the smoke and air ascend. When the heat is to be diminished, the mouth of the furnace is closed with the lid; through the holes of which the air, smoke, and flame pass. The crucibles are to be kept red-hot during eight or ten hours; and in some places much longer, even several days, according to the nature of the calamine. During this time, the zinc rises in vapour from the calamine, unites with the copper, and renders that metal considerably more fusible than it is by itself. To render the metal very fluid, that it may flow into one uniform mass at the bottom, the fire is to be increased a little before the crucibles are taken out, for pouring off the fluid metal into moulds. From 60 pounds of good calamine, and 40 of copper, 60 pounds of brass may be obtained, notwithstanding a considerable quantity of the zinc is dissipated in the operation. The quantity of brass obtained has been considerably augmented since the introduction of the method now commonly practised, of granulating the copper; by which means a larger surface of this metal is exposed to the vapour of zinc, and consequently less of that vapour escapes. To make the finer and more malleable kinds of brass, besides the choice of pure calamine and pure copper,

some

Copper. fome manufacturers cement the brafs a fecond time with calamine and charcoal; and fometimes add to it old brafs, by which the new is faid to be meliorated.

Brafs is brittle when hot; but fo ductile when cold, that it may be drawn into very fine wire, and beat into very thin leaves. Its beautiful colour, malleability, and its fufibility, by which it may be eafily caft into moulds, together with its being lefs liable to ruft than copper, render it fit for the fabrication of many utenfils.

Although zinc be fixed to a certain degree in brafs, by the adhefion which it contracts with the copper; yet when brafs is melted, and expofed to a violent fire, during a certain time, the zinc diffipates in vapours, and even flames away, if the heat be ftrong enough; and if the fire is long enough continued, all the zinc will be evaporated and deftroyed, fo that what remains is copper.

1154 Prince's metal. Prince's metal is made by melting zinc in fubftance with copper; and all the yellow compound metals prepared in imitation of gold are no other than mixtures of copper with different proportions of that femimetal, taken either in its pure ftate, or in its natural ore calamine, with an addition fometimes of iron-filings, *&c.* Zinc itfelf unites moft eafily with the copper; but calamine makes the moft ductile compound, and gives the moft yellow colour. Dr Lewis obferves, that a little of the calamine renders the copper pale; that when it has imbibed about $\frac{1}{12}$ its own weight, the colour inclines to yellow; that the yellownefs increafes more and more, till the proportion comes to almoft one half; that on further augmenting the calamine, the compound becomes paler and paler, and at laft white. The crucibles, in which the fufion is performed in large works, are commonly tinged by the matter of a deep blue colour.

1155 Bell-metal. Bell-metal is a mixture of copper and tin; and tho' both thefe metals fingly are malleable, the compound proves extremely brittle. Copper is diffolved by melted tin eafily and intimately, far more fo than by lead. A fmall portion of tin renders this metal dull-coloured, hard, and brittle. Bell-metal is compofed of about ten parts of copper to one of tin, with the addition commonly of a little brafs or zinc. A fmall proportion of copper, on the other hand, improves the colour and confiftency of tin, without much injuring its ductility. Pewter is fometimes made from one part of copper and twenty or more of tin.

1156 Dr Lewis's obfervations on the fpecific gravity of the metal. It has long been obferved, that though tin is fpecifically much lighter than copper, yet the gravity of the compound, bell-metal, is greater than that of the copper itfelf. The fame augmentation of gravity alfo takes place where the lighter metal is in the greateft proportion; a mixture even of one part of tin with two of copper, turning out fpecifically heavier than pure copper. Moft metallic mixtures anfwer to the mean gravity of the ingredients, or fuch as would refult from a bare appofition of parts. Of thofe tried by Dr Lewis, fome exceeded the mean, but the greater number fell fhort of it; tin and copper were the only ones that formed a compound heavier than the heavieft of the metals feparately.

1157 White copper. White copper is prepared by mixing together equal parts of arfenic and nitre, injecting the mixture into a red-hot crucible, which is to be kept in a moderate fire till they fubfide, and flow like wax. One part of this mixture is injected upon four parts of melted copper, and the metal, as foon as they appear thoroughly united together, immediately poured out. The copper, thus whitened, is commonly melted with a confiderable proportion of filver, by which its colour is both improved and rendered more permanent. The white copper of China and Japan appears to be no other than a mixture of copper and arfenic. Geoffroy relates, that, on repeated fufions, it exhaled arfenical fumes, and became red copper, lofing with its whitenefs, one feventh of its weight.

Iron.

§ 4. *Iron.*

Iron is a metal of a greyifh colour; foon tarnifhing in the air into a dufky blackifh hue; and in a fhort time contracting a yellowifh, or reddifh ruft. It is the hardeft of all metals: the moft elaftic; and, excepting platina, the moft difficult to be fufed. Next to gold, iron has the greateft tenacity of parts; an iron wire, the diameter of which is the tenth part of an inch, being capable of fuftaining 450 pounds. Next to tin, it is the lighteft of all the metals, lofing between a feventh and eighth part of its weight when immerfed in water. When very pure, it may be drawn into wire as fine as horfe-hair; but is much lefs capable of being beaten into thin leaves than the other metals, excepting only lead. 1158 Tenacity of its parts.

Iron grows red-hot much fooner than any other metal; and this, not only from the application of actual fire, but likewife from ftrong hammering, friction, or other mechanic violence. It neverthelefs melts the moft difficultly of all metals except manganefe and platina; requiring, in its moft fufible ftate, an intenfe, bright, white heat. When perfectly malleable, it is not fufible at all by the heat of furnaces, without the addition or the immediate contact of burning fuel; and, when melted, lofes its malleability: all the common operations which communicate one of thefe qualities deprive it at the fame time of the other; as if fufibility and malleability were in this metal incompatible. When expofed to the focus of a large burning mirror, however, it quickly fufed, boiled, and emitted an ardent fume, the lower part of which was a true flame. At length it was changed into a blackifh vitrified fcoria.

From the great wafte occafioned by expofing iron to a red but efpecially to a white heat, this metal appears to be a combuftible fubftance. This combuftion is maintained, like that of all other combuftible fubftances, by contact of air. Dr Hook, having heated a bar of iron to that degree called *white heat,* he placed it upon an anvil, and blowed air upon it by means of bellows, by which it burnt brighter and hotter. Expofed to a white heat, it contracts a femivitreous coat, which burfts at times, and flies off in fparkles. No other metallic body exhibits any fuch appearance. On continuing the fire, it changes by degrees into a dark red calx, which does not melt in the moft vehement heat procurable by furnaces, and, if brought into fufion by additions, yields an opaque black glafs. When ftrongly heated, it appears covered on the furface with a foft vitreous matter like varnifh. In this ftate, pieces of it cohere; and, on being 1159 Iron a combuftible fubftance.

Iron.

1160 The only metal capable of being welded.

being hammered together, weld or unite, without discovering a juncture. As iron is the only metal which exhibits this appearance in the fire, so it is the only one capable of being welded. Those operations which prevent the superficial scorification, deprive it likewise of this valuable property: which may be restored again, by suffering the iron to resume its vitreous aspect; and, in some measure, by the interposition of foreign vitrescible matters; whilst none of the other metals will unite in the smallest degree, even with its own scoria.

1161 Contracts in fusion.

Iron expands the least of all metals by heat. In the act of fusion, instead of continuing to expand, like the other metals, it shrinks; and thus becomes so much more dense, as to throw up such part as is unmelted to the surface; whilst pieces of gold, silver, copper, lead, or tin, put into the respective metals in fusion, sink freely to the bottom. In its return to a consistent state, instead of shrinking like the other metals, it expands; sensibly rising in the vessel, and assuming a convex surface, while the others become concave. This property, first observed by Raumur, excellently fits it for receiving impressions from moulds. By the increase of bulk which the metal receives in congelation, it is forced into the minutest cavities, so as to take the impression far more exactly than the other metals which shrink.

1162 Dissolved by all metals except lead and mercury.

Iron is dissolved by all the metals made fluid, except lead; though none of them act so powerfully upon it as gold: but, as Cramer observes, if the iron contains any portion of sulphur, it can scarcely be made to unite at all with gold.

Among the semimetallic bodies, it is averse to an union with mercury; no method of amalgamating these two having yet been discovered; though quicksilver, in certain circumstances, seems in some small degree to act upon it. A plate of tough iron, kept immersed in mercury for some days, becomes brittle; and mercury will often adhere to and coat the ends of iron pestles used in triturating certain amalgams with saline liquors. Mr Jones has also discovered, that by plunging iron, while heated to an intense white heat, into mercury, the latter will adhere to the surface of the iron, and completely silver it over.

Next to mercury, zinc is the most difficultly combined with iron; not from any natural indisposition to unite, but from the zinc being difficultly made to sustain the heat requisite. The mixture is hard, somewhat malleable, of a white colour approaching to that of silver. Regulus of antimony, as soon as it melts, begins to act on iron, and dissolves a considerable quantity. If the regulus be stirred with a iron rod, it will melt off a part of it. Arsenic likewise easily mingles with iron, and has a strong attraction for it; forsaking all the other metals to unite with this. It renders the iron white, very hard, and brittle.

1163 Prussian blue.

This metal is the basis of the fine blue pigment, called, from the place where it was first discovered, *Berlin* or *Prussian* blue. This colour was accidentally discovered about the beginning of the present century, by a chemist of Berlin, who, having successively thrown upon the ground several liquors from his laboratory, was much surprised to see it suddenly stained with a beautiful blue colour. Recollecting what liquors he had thrown out, and observing the same effects from a similar mixture, he prepared the blue for the use of painters; who found that it might be substituted to ultramarine, and accordingly have used it ever since.

1164 Dr Woodward's recept for.

Several chemists immediately endeavoured to discover the composition of this pigment; and in the year 1724 Dr Woodward published the following process, in the Philosophical Transactions, for making it. "Alkalize together four ounces of nitre, and as much tartar as is directed for charcoal (n° 779). Mix this alkali well with four ounces of dried bullocks blood; and put the whole in a crucible covered with a lid, in which there is a small hole. Calcine with a moderate heat, till the blood be reduced to a perfect coal; that is, till it emits no more smoke or flame capable of blackening any white bodies that are exposed to it. Increase the fire towards the end, so that the whole matter contained in the crucible shall be moderately, but sensibly, red.

"Throw into two pints of water the matter contained in the crucible, while yet red, and gave it half an hour's boiling: decant this first water; and pour more upon the black charry coal, till it becomes almost insipid. Mix together all these waters; and reduce them, by boiling, to about two pints.

"Dissolve also two ounces of martial vitriol, and eight ounces of alum, in two pints of boiling water. Mix this solution when hot with the preceding lixivium also hot. A great effervescence will then be made: the liquors will be rendered turbid; and will become of a green colour, more or less blue; and a precipitate will be formed of the same colour. Filtrate, in order to separate this precipitate; upon which pour spirit of salt, and mix them well together; by which means the precipitate will become of a fine blue colour. It is necessary to add rather too much of the salt than too little, and till it no longer increases the beauty of the precipitate. The next day wash this blue, till the water comes off from it insipid; and then gently dry it."

1165 Mr Geoffroy's theory.

Mr Geoffroy was the first who gave any plausible theory of this process, or any rational means of improving it. He observes, that the Prussian blue is no other than the iron of the vitriol revived by the inflammable matter of the alkaline lixivium, and perhaps a little brightened by the earth of alum; that the green colour proceeds from a part of the yellow ferruginous clax, or ochre, unrevived, mixing with the blue; and that the spirit of salt dissolves this ochre more readily than the blue part; though it will dissolve that also by long standing, or if used in too large quantity. From these principles, he was led to increase the quantity of inflammable matter; that there might be enough to revive the whole of the ferruginous ochre, and produce a blue colour at once, without the use of the acid spirit. In this he perfectly succeeded; and found, at the same time, that the colour might be rendered of any degree of deepness, or lightness, at pleasure. If the alkali is calcined with twice its weight of dried blood, and the lixivium obtained from it poured into a solution of one part of vitriol to six of alum, the liquor acquires a very pale blue colour, and deposits as pale a precipitate. On adding more and more of a fresh solution of vitriol, the colour becomes deeper and deeper, almost to blackness. He imagines, with great probability, that the blue pigment, thus prepared, will prove more durable in the air, mingle more perfectly with other colours, and be less

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leſs apt to injure the luſtre of ſuch as are mixed with or applied in its neighbourhood, than that made in the common manner; the tarniſh to which common Pruſſian blue is ſubject, ſeeming to proceed from the acid, which cannot be ſeparated by any ablution.

1166 Amuſing phenomenon in the preparation.

He takes notice of an amuſing phenomenon which happens upon mixture. When the liquors are well ſtirred together; and the circular motion, as ſoon as poſſible, ſtopped; ſome drops of ſolution of vitriol, (depurated, by long ſettling), let fall on different parts of the ſurface, divide, ſpread, and form curious repreſentations of flowers, trees, ſhrubs, flying inſects, &c. in great regularity and perfection. Theſe continue 10 or 12 minutes: and on ſtirring the liquor again, and dropping in ſome more of the ſolution of vitriol, are ſucceeded by a new picture.

1167 Mr Macquer's theory.

This theory is confirmed by Mr Macquer, in a Memoir printed in the year 1752. He obſerves, that the quantity of phlogiſton communicated to the iron in this proceſs is ſo great, as not only to cauſe the metal reſiſt in a great meaſure the action of acids, and become totally unaffected by the magnet; but by a ſlight calcination it becomes entirely ſimilar to other iron, and is at once deprived of its blue colour. He further obſerves, that fire is not the only means by which Pruſſian blue may be deprived of all the properties which diſtinguiſh it from ordinary iron. A very pure alkali produces the ſame effect. He has alſo diſcovered, that the alkali which has thus deprived the Pruſſian blue of all the properties which diſtinguiſh it from ordinary iron, becomes, by that operation, entirely ſimilar to the phlogiſticated alkali uſed for the preparation of Pruſſian blue.

1168 Phlogiſticated alkali loſes its alkaline properties.

By a more particular examination, he found, that the alkali might become perfectly ſaturated with the colouring matter; ſo that, when boiled on Pruſſian blue, it extracted none of its colour. When the ſalt was thus perfectly ſaturated, it ſeemed no longer to poſſeſs any alkaline qualities. If poured into a ſolution of iron in any acid, a ſingle, homogeneous, and perfect precipitate, was formed; not green, as in Dr Woodward's proceſs, but a perfect Pruſſian blue; which needed no acid to brighten its colour. A pure acid added to the alkali was not in the leaſt neutralized, nor in the leaſt precipitated the colouring matter. From hence Mr Macquer concludes, that, in the making of Pruſſian blue, vitriol is decompoſed; becauſe the iron has a ſtrong attraction for the colouring matter, as well as the acid for the alkali; and the ſum of the attraction of the acid to the alkali, joined to that of the iron for the colouring matter, is greater than the ſingle attraction of the acid to the metal.

1169 Earths do not attract the colouring matter.

Another very important phenomenon is, that earths have not the ſame attraction for this colouring matter that metallic ſubſtances have. Hence, if an alkali ſaturated with this colouring matter be poured into a ſolution of alum, no decompoſition is effected, nor any precipitate formed. The alum continues alum, and the alkali remains unchanged. From this experiment Mr Macquer concludes that alum does not directly contribute to the formation of the Pruſſian blue. The purpoſe he thinks it anſwers is as follows. Fixed alkaline ſalts can never be perfectly ſaturated with phlogiſtic matter by calcination; alkalies, therefore, though calcined with inflammable ſubſtances, ſo as to make a proper lixivium for Pruſſian blue, remain ſtill alkaline. Hence, when mixed with a ſolution of green vitriol, they form, by their purely alkaline part, a yellow precipitate, ſo much more copious, as the alkali is leſs ſaturated with phlogiſton. But nothing is more capable of ſpoiling the fine colour of the Pruſſian blue, than an admixture of this yellow precipitate: it is therefore neceſſary to add a quantity of alum, which will take up the greateſt part of the purely alkaline ſalt, and of conſequence the quantity of yellow ferruginous precipitate is much diminiſhed. But the earth of alum, being of a fine ſhining white, does not in the leaſt alter the purity of the blue colour, but is rather neceſſary to dilute it. From all this it follows, that it is a matter of indifference whether the green precipitate is to be again diſſolved by an acid, or the alkaline part of the lixivium ſaturated with alum or with an acid, before the precipitate is formed. The latter indeed ſeems to be the moſt eligible method.

1170 Blue producible from other alkalies.

Moſt alkalies obtained from the aſhes of vegetables, being combined, by their combuſtion, with a portion of inflammable matter, are capable of furniſhing a quantity of Pruſſian blue, proportionable to the quantity of colouring matter they contain, even without the neceſſity of mixing them with a ſolution of iron; becauſe they always contain a little of this metal diſſolved, ſome of which may be found in almoſt all vegetables; therefore it is ſufficient to ſaturate them with an acid. Henckel obſerved the production of this blue in the ſaturation of the foſſile alkali, and recommended to chemiſts to inquire into its nature.

1171 Mr Scheele diſcovers the colouring matter of Pruſſian blue.

The theories of Geoffroy, Macquer, &c. however, with reſpect to Pruſſian blue, have now given place to that of Mr Scheele; who has examined the ſubſtance with the utmoſt care, and found the colouring matter to conſiſt of an extremely volatile ſubſtance, capable of uniting with and neutralizing alkalies, but eaſily expelled from them by any other acid, even by that of fixed air.

1172 Lixivium ſanguinis loſes its colouring property by expoſure to the air.

He begins his diſſertation on this ſubject by obſerving, that the ſolution of alkali calcined with dried blood, which he calls *lixivium ſanguinis*, by expoſure to the air, loſes its property of precipitating the iron of a blue colour; and that the precipitate thus obtained is entirely ſoluble in the acid. In order to determine whether the air had thus undergone any change, he put ſome newly prepared lixivium into a glaſs veſſel well ſealed with roſin; but after ſome time finding no change on the lixivium, or on the air contained in the veſſel, he began to think that this might be occaſioned by the abſence of fixed air, which always abounds in the open atmoſphere, though not in any confined portion of it, at leaſt in an equal proportion.

1173 Suppoſed to ariſe from the fixed air abſorbed from the atmoſphere.

Having therefore filled a glaſs veſſel with fixed air, he poured into it a little lixivium ſanguinis; and next day found, that it threw down from green vitriol a precipitate entirely ſoluble in acids. With other acids he obtained no precipitate.

1174 The matter fixed by the addition of ſome green vitriol to the lixivium.

On inverting the experiment, and mixing ſome green vitriol with lixivium ſanguinis, the mixture grew yellow; and he found this addition capable of fixing the colouring matter ſo that neither the acid of fixed air nor any other could expel it from the alkali. For having poured the mixture abovementioned into a ſolution of green vitriol, and afterwards ſuperſaturated the

the lixivium with acid, he obtained a conſiderable quantity of blue. To the ſame lixivium ſanguinis, in which a ſmall quantity of green vitriol was diſſolved, he afterwards added of the other acids ſomewhat more than was neceſſary for its ſaturation; and though this was

1175 Calx of iron ſoluble in lixivium ſanguinis;

done, a conſiderable quantity of Pruſſian blue was afterwards obtained. Again, having precipitated a ſolution of green vitriol with alkali, and boiled the precipitate for ſome minutes in lixivium ſanguinis, part of it was diſſolved: the filtered lixivium underwent no change when expoſed to the open air or to the aerial acid, and precipitated the ſolution of vitriol of a blue; and though the lixivium was ſuperſaturated with acid, and ſome green vitriol added, a very beautiful Pruſſian

1176 But not when highly dephlogiſticated.

blue was obtained. This, however, will not hold when a perfectly dephlogiſticated calx of iron is employed, of which none can be diſſolved by the lixivium ſanguinis; nor will any Pruſſian blue be obtained by precipitating with lixivium ſanguinis a perfectly dephlogiſticated ſolution of iron in nitrous acid.

1177 The colouring matter taken up by the air after it has been expelled by acids.

To determine what had become of the colouring matter in thoſe experiments where it ſeemed to have been diſſipated, ſome lixivium ſanguinis was poured into a veſſel filled with aerial acid. It was kept well corked during the night, and next day a piece of paper dipped in a ſolution of green vitriol was fixed to the cork, pencilling it over with two drops of a ſolution of alkali in water. The paper was thus ſoon covered with precipitated iron; and on being taken out two hours afterwards, and dipped in muriatic acid, became covered with moſt beautiful Pruſſian blue. The ſame thing happened when lixivium ſanguinis ſuperſaturated with vitriolic acid was employed; for in this caſe alſo the air was filled with the colouring matter capable of being in like manner abſorbed by the calx of iron. But though from theſe experiments it is plain that acids expel this colouring ſubſtance from the lixivium, a given quantity of air is only capable of receiving a certain quantity of it; for the ſame mixture removed into another veſſel imparts the colouring property to the air it contains according to its quantity. On putting perfectly dephlogiſticated calx of iron upon the papers, no Pruſſian blue was formed; but the muriatic acid diſſolved the calx entirely.

1178 The colouring matter expelled by diſtillation with vitriolic acid.

Our author having now aſſured himſelf that acids really attract the alkali more than the colouring matter, proceeded to try the effects of diſtillation. Having therefore ſuperſaturated ſome lixivium ſanguinis with vitriolic acid, he diſtilled the mixture in a glaſs retort with a gentle fire. When about one-third had paſſed over, he changed the receiver, and continued the operation till one half was diſtilled. The firſt product had a peculiar taſte and ſmell; the air in the receiver was filled with colouring matter, and the aqueous fluid was alſo ſtrongly impregnated with it, as appeared by its forming a fine Pruſſian blue with phlogiſticated calx of iron. Part of it being expoſed to the open air for ſome hours, entirely loſt its power, and the product of the ſecond operation was no other than water mixed with a little vitriolic acid.

1179 Attempts to procure the colouring matter by itſelf.

The next ſtep was to procure, if poſſible, the colouring matter by itſelf; and this he attempted to obtain from the Pruſſian blue, rather than the lixivium ſanguinis, as he would thus not only avoid the troubleſome calcination of the alkali and blood, but obtain the colouring matter im much larger quantity than could be done from the lixivium. On examining ſeveral kinds of this pigment, he found in them evident marks of ſulphur, volatile alkali, vitriolic acid, and volatile ſulphureous acid; all of which ſubſtances are to be found in the lixivium ſanguinis as well as in that of ſoot, and adhere to the precipitate in the preparation of Pruſſian blue. Finding, however, that he could not obtain his purpoſe by any kind of analyſis of theſe by

1180 Neutral ſalt for diſcovering iron in mineral waters.

fire alone, he had recourſe to a neutral ſalt uſed by chemiſts for diſcovering iron in mineral waters. This is formed by digeſting cauſtic fixed alkali on Pruſſian blue, which effectually extracts the colour from it even in the cold, in a very ſhort time, and being neutralized, may eaſily be reduced into a dry form. But it is not entirely to be depended upon for this purpoſe; for it always contains ſome iron which indeed is the medium of its connection with the alkali. The lixivium ſanguinis is preferable, though even this contains ſome iron, as well as the lixivium of ſoot; our author's experiments, however, were made with the neutral ſalt, for the reaſon already mentioned.

1181 Effects of diſtilling this ſalt with oil of vitriol.

1. An ounce of the ſalt was diſſolved in a glaſs retort in four ounces of water, afterwards adding three drachms of concentrated vitriolic acid; and the mixture was diſtilled with a gentle fire. The maſs grew thick as ſoon as it began to boil; from a great quantity of Pruſſian blue, a quantity of the colouring matter appeared by the ſmell to penetrate the lute: and part of it was abſorbed by the air in the receiver, as in former experiments. The diſtillation was continued till about an ounce had paſſed into the receiver. The blue maſs remaining in the retort was put into a ſtrainer, and a piece of green vitriol put into the liquid which paſſed through; but by this laſt no Pruſſian blue was produced. The blue which remained in the filter was again treated with lixivium tartari: the ſolution freed from its ochre by filtration, and the clear liquor committed a ſecond time to diſtillation with vitriolic acid. Pruſſian blue was again ſeparated, though in ſmaller quantity than before, and the colouring matter came over into the receiver. After one third of the matter had paſſed over, that which had been obtained by the firſt diſtillation was added to it, the Pruſſian blue was ſeparated from the lixivium in the retort, and extracted a third time. Some Pruſſian blue was formed again, though in much ſmaller quantity; whence it is apparent that Pruſſian blue may at laſt be totally decompoſed by means of alkali. Lime, or terra ponderoſa, likewiſe extract the blue colour, and ſhow the ſame phenomena as alkali.

1182 Colouring matter unites with volatile alkali.

With volatile alkali a compound, conſiſting of the alkali, iron, and colouring matter, is formed, which ſhows the ſame phenomena with that formed with fixed alkali. By diſtillation *per ſe* after it has been diſſolved in water, the liquor grows thick in conſequence of a ſeparation of Pruſſian blue, and volatile alkali paſſes over into the receiver. This volatile ſpirit is impregnated with the colouring matter; it is not precipitated by lime water; but green vitriol is precipitated by it; and on adding an acid, Pruſſian blue is formed. If a piece of paper dipped in a ſolution of green vitriol, be expoſed to the vapour of this alkali, it is ſoon decompoſed; and if the ſame be pencilled over with muriatic acid, it inſtantly becomes blue.

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blue. On exposing the liquor to the open air, it all evaporates, leaving pure water behind.

1183 How to free the colouring matter perfectly from its vitriolic taint.

As in all the operations with vitriolic acid hitherto related, some small quantity of it passes into the receiver, our author shows how to deprive the colouring matter, of that vitriolic taint. For this purpose nothing more is necessary than to put a little chalk into the matter, and redistil it with a very gentle heat; the acid unites with the chalk, and the colouring matter goes over in its greatest purity.

1184 How to prevent the escape of the colouring matter thro' the lute.

In order to hinder, as much as possible, the escape of the volatile colouring matter through the lute, he makes use of a small receiver, putting into it a little distilled water, and placing it so that the greater part shall be immersed in cold water during the operation. The water impregnated with this colouring matter has a peculiar but not disagreeable smell, a taste somewhat approaching to sweet, and warm in the mouth, at the same time exciting cough.

1185 This matter neither acid nor alkaline.

When rectified as above directed, it appears to be neither acid nor alkaline; for it neither reddens paper dyed with lacmus, nor does it restore the colour of such paper after it has been made red; but it renders turbid the solutions of soap and hepar sulphuris. The same liquor mixed with fixed alkali, though it contains a superabundance of colouring matter, restores the blue colour of paper reddened by an acid. By distillation to dryness, there goes over a part of the colouring matter which disengages itself from the alkali; the residuum is soluble in water, and has all the properties of the best lixivium sanguinis; but, like the true lixivium, it is decomposed by all the acids, even by that of fixed air.

1186 Forms a kind of ammoniacal salt with volatile alkali.

With caustic volatile alkali it forms a kind of ammoniacal salt; which, however, always smells volatile, though the colouring matter be in ever so great proportion. By distillation the whole instantly rises, and nothing but pure water is left in the retort.

1187 Dissolves magnesia alba.

Magnesia precipitated from Epsom salt by caustic volatile alkali, was dissolved in the colouring matter by allowing them to stand together for several days in a warm close bottle. On exposure to the open air, the magnesia separated from it by its superior attraction for aerial acid, and formed on the surface of the water a pellicle like that of cream of tartar. This solution was likewise decomposed by alkalies and lime-water.

1188 Very little terra ponderosa.

The colouring matter dissolves but a very small quantity of terra ponderosa, which may be afterwards precipitated by vitriolic and even by aerial acid.

1189 Dissolves lime, but not clay.

Pure clay, or the basis of alum, is not attacked by it. Lime is dissolved in a certain quantity. The superabundant portion should be separated by filtration; and as the liquor contains, besides the combined lime, the portion which water itself is able to take up, in order to free it from this, precisely the same quantity of water impregnated with aerial acid is to be added as is requisite for precipitating an equal quantity of lime-water. The colouring matter, thus saturated with lime, is to be filtered again, and then to be preserved in a well closed bottle to prevent the access of fixed air. This solution is decomposed by all the acids, and by the pure or caustic alkalies. By distillation the colouring matter rises, and nothing but pure lime is left in the retort.—This solution of lime appears to our author to be so perfectly saturated, that he employed it in preference to any other in the experiments he made on metals, and which we are now about to relate.

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1190 The solution of lime the most proper for experiments on metals.

1191 Silver, quickfilver, and iron precipitated by the colouring matter.

From the trials made by Mr Scheele, it appears that the colouring matter has no effect upon any metal or metallic solution, excepting those of silver and quicksilver in nitrous acid, and that of iron in fixed air. The first is precipitated in a white powder: the second in a black one; and the third assumes a sea-green colour, which afterwards turns to blue.

1192 Its effects on metallic calces;

With metallic calces it produces the following phenomena. 1. Gold precipitated by aerated alkali becomes white. 2. The fixed air is disengaged from a precipitate of silver with a slight effervescence. 3. Calx of mercury is dissolved, and yields crystals by gentle evaporation. 4. The calx of copper precipitated by aerated alkali effervesces, and assumes a faint citron colour. 5. Calx of iron precipitated from its solution in the vitriolic acid by the same alkali, effervesces, and assumes a dark blue colour. 6. Precipitated cobalt shows some signs of effervescence, and changes into a yellowish brown colour. The other calces are not acted upon.

1193 On metallic solutions.

The precipitating liquor abovementioned, poured into metallic solutions, produces the following appearances by means of double elective attraction. 1. Gold is precipitated of a white colour, but by adding a superabundant quantity of the precipitating liquor the calx is redissolved. The second solution is colourless as water. 2. Silver is precipitated in form of a white substance of the consistence of cheese; by adding more of the liquor the precipitate is redissolved, and the solution is not decomposed either by sal ammoniac or marine acid. 3. Corrosive sublimate apparently undergoes no change, though it is in reality decompounded; the calx being dissolved in the colouring matter. Mercury dissolved in the nitrous acid without heat, is precipitated in form of a black powder. 4. The solutions of tin and bismuth are precipitated, but the calx is not acted upon by the colouring matter. 5. The same effects are produced on the solution of butter of antimony, as well as on that of well dephlogisticated calx of iron. 6. Blue vitriol is precipitated of a yellow citron colour: if more of the precipitating liquor be added, the precipitate is redissolved into a colourless liquor and a colourless solution of the same calx is likewise obtained by volatile alkali. On adding more of the solution of blue vitriol, the solution likewise disappears, and the liquor assumes a green colour. Acids dissolve a portion of this precipitate, and the remainder is white. The muriatic acid dissolves the precipitate completely, but lets it fall again on the addition of water. 7. The solution of white vitriol yields a white precipitate, which is not redissolved by addition of the precipitating liquor, but is soluble in acids. These solutions smell like the colouring matter, which may be separated from them by distillation. 8. Green vitriol is precipitated first of a yellowish brown colour, which soon changes to green, and then becomes blue on the surface. Some hours afterwards the precipitate subsides to the bottom of the vessels, and then the whole mixture turns blue; but on adding any acid the precipitate becomes instantly blue. If a very small quantity of green vitriol be put into the precipitating liquor, the

Iron.

the precipitate is entirely diſſolved, and the whole aſſumes a yellow colour. 7. Solution of cobalt lets fall a browniſh yellow precipitate, which is not diſſolved by adding more of the precipitating liquor, neither is it ſoluble in acids. By diſtillation the colouring matter goes over into the receiver.

1194 Inveſtigation of the conſtituent part of the colouring matter.

Laſtly, our author undertook an inveſtigation of the conſtituent parts of the colouring matter itſelf; and in this he ſucceeded in ſuch a manner as muſt do honour to his memory, at the ſame time that it promiſes to be a real and laſting improvement to ſcience, by ſhowing a method of preparing this valuable pigment without that nauſeous and horrid ingredient, blood, which is now uſed in great quantities for that purpoſe.—His firſt hint concerning this matter ſeems to have been taken from an obſervation of the air in his receiver accidentally taking fire from the neighbourhood of a candle. It burned without any exploſion, and he was able to inflame it ſeveral times ſucceſſively. Wiſhing to know whether any fixed air was contained in the colouring matter, he filled a retort half full of the liquor containing the colouring matter, and applying a receiver immediately after, gave the retort a briſk heat. As ſoon as the receiver was filled with thick vapours of the colouring matter, he disjoined it, and, inflaming the vapour by a little burning ſulphur introduced into the cavity, found that the air which remained threw down a precipitate from lime-water. "Hence (ſays he) it may be concluded, that the aerial acid (A) and phlogiſton exiſt in this colouring matter."

1195 Inflammability of the colouring matter.

1196 Aerial acid and phlogiſton ſuppoſed to exiſt in it.

1197 Pruſſian blue yields volatile alkali by diſtillation.

It has been aſſerted by ſeveral chemiſts, that Pruſſian blue by diſtillation always yields volatile alkali.—To determine this, Mr Scheele prepared ſome exceedingly pure from the precipitating liquor abovementioned and green vitriol; diſtilling it afterwards in a glaſs retort, to which he adapted a receiver containing a little diſtilled water. The operation was continued till the retort became red-hot. In the receiver was found the colouring matter and volatile alkali, but no oil; the air in the receiver was impregnated with aerial acid, and the ſame colouring matter; the reſiduum was very black, and obeyed the magnet. On ſubſtituting, inſtead of the Pruſſian blue, the precipitates of other metallic ſubſtances precipitated by the Pruſſian alkali, the reſults were: 1. The yellowiſh brown precipitate of cobalt yielded the very ſame products with Pruſſian blue itſelf; the reſiduum in the retort was black. 2. The yellow precipitate of copper took fire, and emitted, from time to time, ſparks during the diſtillation. It produced little colouring matter, but a greater quantity of aerial acid and volatile alkali than had been obtained by the former precipitates. A ſublimate aroſe in the neck of the retort, but in too ſmall a quantity to make any experiment; the reſiduum was reduced copper. 3. The precipitate of zinc yielded the ſame with Pruſſian blue. 4. That of ſilver yielded likewiſe volatile alkali and fixed air, but chiefly colouring matter; a ſublimate containing ſome ſilver aroſe into the neck of the retort; the reſiduum was reduced ſilver. 5. Calx of mercury cryſtallized by means of the colouring matter, yielded ſome of that matter, but ſcarce any mark of volatile alkali. Some mercury, with a portion of the original compound, aroſe in the neck of the retort.

1198 Appearances on diſtilling other precipitates thrown down by Pruſſian alkali.

1199 Ingredients contained in the colouring matter.

From theſe experiments Mr Scheele concluded, that the colouring matter of Pruſſian blue was compoſed of volatile alkali and an oily matter. He was confirmed in his conjecture, by obtaining Pruſſian blue from green vitriol and ſpirit of hartſhorn recently diſtilled on the addition of muriatic acid. The ſame product was obtained by means of the volatile ſpirit drawn from ox's blood; ſo that nothing now remained, but to imitate theſe natural proceſſes by artificially combining the two ingredients together. For this purpoſe he diſtilled a mixture of volatile ſalt and unctuous oil; a mixture of the ſame alkali with animal fat, and with oil of turpentine; a mixture of quick-lime, ſal ammoniac, and auxunge, with others of a ſimilar kind; but in vain. He began therefore to conclude, that as long as the volatile alkali contained any water, it could not enter into an union ſufficiently intimate with the other principles to form the colouring matter; and finding alſo that the coal of blood, mixed with ſalt of tartar, yielded very good lixivium ſanguinis, he concluded that no oily matter was neceſſary for the ſucceſs of the experiment.

1200 Unſucceſsful attempts to prepare it artificially

1201 True method of forming it.

Thus was our author led to make the following deciſive trials, which at once accompliſhed his purpoſe, and ſhowed the truth of the principles he had aſſumed. Three table-ſponſuls of charcoal powder were mixed with an equal quantity of alkali of tartar, and the mixture put into a crucible. A ſimilar mixture was put into another crucible, and both put into a fire, and kept red-hot for about a quarter of an hour. One of them was then taken out, and the contents thrown, while perfectly red-hot, into eight ounces of water. At the ſame time he put into the other quantity an ounce of ſal ammoniac in ſmall pieces, agitating the whole briſkly together, and taking care at the ſame time to puſh the ſal ammoniac down towards the bottom of the crucible, which he replaced in the fire. Obſerving in two minutes after, that no ammoniacal vapours aroſe, the whole maſs was thrown, when red-hot, into eight ounces of water. The former lixivium, into which no ſal ammoniac had been put, yielded no Pruſſian blue; but the latter ſhowed the ſame phenomena with the beſt lixivium ſanguinis, and produced a great quantity of blue. By mixing plumbago with the alkali inſtead of charcoal, a tolerable lixivium was obtained.

1202 Volatile alkali capable of uniting with phlogiſton and fixed alkali, ſo as to ſuſtain a great degree of heat.

"From theſe experiments (ſays Mr Scheele), it appears, that the volatile alkali is capable of uniting with the carbonaceous matter, after it has been ſubtilized by a ſtrong heat; that it thus acquires the remarkable property of combining ſo firmly with ſalt of tartar as to be able to ſuſtain the moſt violent degree of heat; and when this lixivium is diſſolved in water, there is obtained lixivium ſanguinis, as it is called.—It is now eaſy to explain what happens in the diſtillation

(A) This reaſoning ſeems not to be ſufficiently concluſive; for late experiments have ſhown that inflammation is generally attended with the production of fixed air, which could not be proved to have an exiſtence either in the materials or common atmoſphere before.

Iron.

lation of Pruſſian blue, as well as that of the other abovementioned metallic precipitates.—In the diſtillation of Pruſſian blue, for inſtance, the calx of iron attracts a portion of phlogiſton from the colouring matter. The aerial acid being thus diſengaged, muſt go over into the receiver with the volatile alkali, which is ſet free at the ſame inſtant; but as the calx of iron in the heat of this diſtillation cannot unite with more phlogiſton, a portion of the colouring matter, not decompoſed, muſt likewiſe ariſe. If the calx of iron could combine with the whole of the phlogiſton, there would come nothing over into the reciever but aerial acid and volatile alkali. In order to prove this, I diſtilled a mixture of ſix parts of mangane ſe finely powdered, and one part of pulverized Pruſſian blue, and obtained nothing but aerated volatile alkali, without the leaſt mark of colouring matter."

1203 Appearances on diſtilling Pruſſian blue accounted for.

1204 Colouring matter kept from riſing by mangane ſe.

1205 The colouring matter can ſeparate only mercury and ſilver from their ſolution in nitrous acid.

Mr Scheele further remarks, that this colouring matter may probably be obtained in an aerial form, though he had not been able to do ſo. It is alſo worth notice, that, excepting the ſolutions of ſilver and mercury in nitrous acid, the colouring matter of Pruſſian blue is not able to decompoſe any other by a ſingle elective attraction. Now, as we know that Pruſſian blue is not ſoluble in acids, it naturally follows, that the colouring matter has a greater affinity with iron than acids have, notwithſtanding there is no precipitation perceived when this matter is mixed with the ſolution of vitriol of iron. "It may not be eaſy (ſays Mr Scheele) to give a ſatisfactory explanation of this phenomenon."

1206 Nitre alkalized by iron.

Iron deflagrates with nitre, and renders the ſalt alkaline and cauſtic. A part of the iron is thus rendered ſoluble, along with the alkalized ſalt. A mixture of equal parts of iron filings and nitre, injected into a ſtrongly heated crucible, and, after the detonation, thrown into water, tinges the liquor of a violet or purpliſh blue colour. This ſolution, however, is not permanent. Though the liquor at firſt paſſes through a filter, without any ſeparation of the iron; yet, on ſtanding for a few hours, the metal falls to the bottom, in form of a brick-coloured powder. Volatile alkalies inſtantly precipitate the iron from this fixed alkaline ſolution.

1207 Iron filings and ſulphur take fire ſpontaneouſly.

Iron readily unites with ſulphur; and when combined with it, proves much eaſier of fuſion than by itſelf. A mixture of iron filings and ſulphur, moiſtened with water, and preſſed down cloſe, in a few hours ſwells and grows hot; and, if the quantity is large, burſts into flame.

By cementation with inflammable maters, iron imbibes a larger quantity of phlogiſton; and becomes much harder, leſs malleable, and more fuſible. It is then called *ſteel*. See METALLURGY, and STEEL.

§ 5. *LEAD.*

LEAD is a pale or livid-white metal, ſoon loſing its brightneſs in the air, and contracting a blackiſh or greyiſh aſh-colour. It is the ſofteſt and moſt flexible of all metallic bodies; but not ductile to any great degree, either in the form of wire or leaf; coming far ſhort, in this reſpect, of all other metals. It has alſo the leaſt tenacity of all metallic bodies; a leaden wire of [illegible] of an inch diameter being capable of ſupporting only 29[illegible] pounds. Lead has, however, a conſiderable ſpecific gravity; loſing, when immerſed in water, between [illegible] and [illegible] of its weight. It is of all metals the moſt fuſible, excepting only tin and biſmuth.

1208 Has very little tenacity.

1209 Sheet-lead.

The plumbers caſt thin ſheets of lead upon a table or mould, covered with a woollen, and above this with a linen, cloth, without burning or ſcorching the cloths. The melted lead is received in a wooden caſe without a bottom; which being drawn down the ſloping table by a man on each ſide, leaves a ſheet of its own width, and more or leſs thin according to the greater or leſs celerity of its deſcent. For thick plates, the table is covered over with moiſtened ſand, and the liquid metal conducted evenly over it, by a wooden ſtrike, which bears on a ledge at each ſide.

1210 Advantages of milled lead precarious.

Some have preferred, for mechanic uſes, the milled lead, or flatted ſheets, to the caſt; as being more equal, ſmooth, and ſolid. But whatever advantage of this kind the milled ſort may appear to have at firſt, they are not found to be very durable. When the lead is ſtretched between the rollers, its cavities muſt neceſſarily be enlarged. The particles of metal that may be ſqueezed into them can have no union or adheſion with the contiguous particles; and of conſequence, muſt be liable, from bending, blows, jarrs, &c. to ſtart out again, and leave the maſs ſpongy and porous.

1211 Rendered ſonorous.

Lead yields the dulleſt and weakeſt ſound of all metallic bodies. Reaumer obſerves, that it is rendered ſonorous by caſting a ſmall quantity into a ſpherical or elliptical ſegment, as in the bottom of an iron-laddle; from hence he conjectures, that the ſound of the ſonorous metals might be improved for the bells of clocks, &c. by giving them a ſimilar form.

1212 Calcined.

Though this metal very ſoon loſes its luſtre, and tarniſhes in the air, it reſiſts much longer than iron or copper the combined action of air and water, before it is decompoſed or deſtroyed; and hence it is exceedingly uſeful for many purpoſes to which theſe metals can by no means be applied. When juſt become fluid, lead looks bright like quickſilver; but immediately contracts a variouſly coloured pellicle on the ſurface. If this is taken off, and the fire continued, a freſh pellicle will always be formed, till the metal is by degrees changed into a duſky powder or calx. The injection of a little fat, charcoal-powder, or other inflammable matter, prevents this change, and readily revives the calx into lead again. It is ſaid, that lead, recovered from its calces, proves ſomewhat harder and whiter than at firſt, as well as leſs ſubject to tarniſh in the air.

1213 Minium.

The blackiſh calx or aſhes of lead become of a very different appearance if the calcination is continued with a fire ſo moderate as not to melt them, and particularly if expoſed to flame. By this treatment it is ſaid that they become firſt yellow; then they are called *maſſicot* or *yellow lead*. This colour becomes gradually more and more intenſe, till at laſt the calx is of a deep red; and then is called *minium* or *red lead*; but it is certain, that by proper management this calx never becomes yellow, aſſuming a reddiſh colour from the beginning. Too great a heat makes it irrecoverably yellow. It can be more eaſily prepared without

expoſure

Lead. exposure to the flame. The degree of heat necessary for converting it into minium is between 600 and 700 of Fahrenheit.

1214 Litharge. If instead of keeping this calx in a continued moderate heat, it be suddenly fused, the matter then puts on a foliated appearance, changing to a dull kind of brick-colour when powdered, and is then called *litharge*. Most of this substance is produced by refining silver with lead (see Refining): and is of two kinds, white and red. These two are distinguished by the names of *litharge of gold*, and *litharge of silver*. The most perfect is that called *litharge of gold*: the pale sort contains a considerable proportion of lead in its metallic state; and even the highest coloured litharge is seldom free from a little metallic lead, discoverable and separable by melting the mass in a crucible; when the lead subsides to the bottom.

1215 Phenomena with other metals. Lead mingles in fusion with all the metals except iron, with which it refuses any degree of union as long as the lead preserves its metallic form. On continuing the fire, the lead, scorifying or calcining, absorbs the phlogistic principle of the iron, and consequently promotes the calcination of that metal; both being at length reduced to calces. The fusible calx of lead easily unites with the calx of iron, and both melt together into an opaque brown or blackish glass. Copper does not unite with melted lead till the fire is raised so high as to make the lead smoke and boil, and of a bright red heat. Pieces of copper, now thrown in, soon dissolve and disappear in the lead: the mixture, when cold, is brittle, and of a granulated texture. The union of these two metals is remarkably slight. If a mixture of copper and lead is exposed to a fire no greater than that in which lead melts, the lead almost entirely runs off by itself; a separation of which no other example is known. What little lead is retained in the pores of the copper, may be scorified, and melted out, by a fire considerably less than is sufficient to fuse copper. If any of the copper is carried off by the lead, it swims unmelted on the surface.

Gold and silver are both dissolved by lead in a slight red heat. They are both rendered extremely brittle by the minutest quantity of this metal; though lead is rendered more ductile by a small quantity of either of them. In cupellation, a portion of lead is retained by gold, but silver parts with it all. On the other hand, in its eliquation from copper, if the copper contains any of the precious metals, the silver will totally melt out with the lead, but the gold will not. The attraction of lead to copper, however slight, is greater than that of copper to iron: a mixture of copper and iron being boiled in melted lead, the copper is imbibed by the lead, and the iron thrown up to the top. Silver is in like manner imbibed from iron by lead; whilst tin, on the contrary, is imbibed from lead by iron. If two mixtures, one of lead and tin, and another of iron and silver, be melted together, the result will be two new combinations, one of the tin with the iron at the top, the other with the lead and silver at the bottom: how carefully soever the matter be stirred and mixed in fusion, the two compounds, when grown cold, are found distinct, so as to be parted with a blow.

This metal is soluble in alkaline lixivia and expressed oils. Plates of lead boiled in alkaline lixivia, have a small part dissolved, and a considerable quantity corroded: the solution stains hair black. Lead, fused with fixed alkaline salts, is in part corroded into a dark-coloured scoria, which partially dissolves in water. Expressed oils dissolve the calces of lead, by boiling, in such large quantities as to become thick and consistent: hence plasters, cements for water-works, paint for preserving nets, &c. Acids have a greater affinity with leads than oils have. If the common plaster, composed of oil and litharge, be boiled in distilled vinegar, the litharge will be dissolved, and the oil thrown up to the top. The oil thus recovered, proves soluble like essential oils in spirit of wine; a phenomenon first taken notice of by Mr Geoffroy. Tin. 1216 Soluble in alkalies and in oils.

§ 6. *Tin.*

The colour of this metal resembles silver, but is somewhat darker. It is softer, less elastic, and sonorous, than any other metal except lead. When bent backwards and forwards, it occasions a crackling sound, as if torn asunder. It is the lightest of all the malleable metals, being little more than seven times specifically heavier than water. The tenacity of its parts also is not very considerable; a tin wire of $\frac{1}{10}$ of an inch diameter being able to support only $49\frac{1}{4}$ pounds.

Tin is commonly reckoned the least ductile of all metals except lead; and certainly is so, in regard to ductility into wire, but not in regard to extensibility into leaves. These two properties seem not to be so much connected with one another as is generally imagined. Iron and steel may be drawn into very fine wire, but cannot be beat into leaves. Tin, on the other hand, may be beat into very thin leaves, but cannot be drawn into wire: gold and silver possess both properties in a very eminent degree; whilst lead, notwithstanding its flexibility and softness, cannot be drawn into fine wire, or beat into thin leaves. It melts the most easily of all the metals; about the 430th degree of Fahrenheit's thermometer. Heated till almost ready to melt, it becomes so brittle that large blocks may be easily beat to pieces by a blow. The purer sort, from its facility of breaking into long shining pieces, is called *grain-tin*. Melted, and nimbly agitated at the instant of its beginning to congeal, it is reduced into small grains or powder. 1217 Capable of being beat into thin leaves.

With the heat necessary for fusion, it may also be calcined; or at least so far deprived of its phlogiston as to appear in the form of a grey calx, which may be entirely reduced to tin by the addition of inflammable matter. The calcination of tin, like that of lead, begins by the melted metal losing its brightness, and contracting a pellicle on its surface. If the fire is raised to a cherry-red, the pellicle swells and bursts, discharging a small bright flame of an arsenical smell. By longer continuance in the fire, the metal is converted first into a greyish, and then into a perfectly white calx, called *putty*, which is used for polishing glass and other hard bodies. 1218 Calcined.

The calx of tin is the most refractory of all others. Even in the focus of a large burning mirror, it only softens a little, and forms crystalline filaments. With

glass

Tin. glaſs of biſmuth, and the ſimple and arſenicated glaſſes of lead, it forms opaque milky compounds. By this property it is fitted for making the baſis of the imperfect glaſſes called *enamels*; (ſee GLASS and ENAMEL). The author of the Chemical Dictionary relates, "that having expoſed very pure tin, ſingly, to a fire as ſtrong as that of a glaſs-houſe furnace, during two hours, under a muffle, in an uncovered teſt, and having then examined it, the metal was found covered with an exceedingly white calx, which appeared to have formed a vegetation; under this matter was a reddiſh calx, and an hyacinthine glaſs; and laſtly, at the bottom was a piece of tin unaltered. The experiment was ſeveral times repeated with the ſame ſucceſs."

1219 Affinity of tin with arſenic.

Nitre deflagrates with tin, and haſtens the calcination of this as well as of other imperfect metals. The vapours which riſe from tin, by whatever method it is calcined, have generally an arſenical ſmell. Tin melted with arſenic falls in great part into a whitiſh calx: the part which remains uncalcined proves very brittle, appears of a white colour, and a ſparkling plated texture, greatly reſembling zinc. The arſenic is ſtrongly retained by the tin, ſo as ſcarcely to be ſeparable by any degree of fire; the tin always diſcovering, by its augmentation in weight, that it holds a portion of arſenic, though a very intenſe fire has been uſed. Hence, as the tin ores abound in arſenic, the common tin is found alſo to participate of that mineral.

1220 Arſenic ſeparable from tin.

Henckel diſcovered a method of ſeparating actual arſenic from tin; namely, by ſlowly diſſolving the tin in eight times its quantity of an aqua-regia made with ſal ammoniac, and ſetting the ſolution to evaporate in a gentle warmth: the arſenic begins to concrete whilſt the liquor continues hot, and more plentifully on its growing cold, into white cryſtals. M. Margraaf, in the Berlin Memoirs for 1746, has given a more particular account of this proceſs. He obſerves, that the white ſediment which at firſt ſeparates during the diſſolution, is chiefly arſenical; that Malacca tin, which is accounted one of the pureſt ſorts, yielded no leſs than ¹th its weight of arſenical cryſtals; that ſome ſorts yielded more; but that tin extracted from a particular kind of ore, which contained no arſenic, afforded none. That the cryſtals were truly arſenical, and appeared from their being totally volatile; from their ſubliming (a little fixed alkaline ſalt being added to abſorb the acid) into a colourleſs pellucid concrete; from the ſublimate, laid on a heated copper-plate, exhaling in fumes of a garlic ſmell; from its ſtaining the copper white: and from its forming, with ſulphur, a compound ſimilar to the yellow or ſulphurated arſenic. He found that the arſenic was ſeparable alſo by means of mercury; an amalgam of tin being long triturated with water, and the powder which was waſhed off committed to diſtillation, a little mercury came over,

1221 and bright arſenical flowers aroſe in the neck of the

Dr Lewis's obſervation. retort. Dr Lewis obſerves, that the crackling noiſe of tin in bending may poſſibly ariſe from its arſenic; as thoſe operations which are ſaid to ſeparate arſenic from the metal, likewiſe deprive it of this property.

Tin may be allayed, in any proportion, with all metals by fuſion: but it abſolutely deſtroys their ductility, and renders them brittle, as in bell-metal; whence this metal has obtained the name of *diabolus metallorum*.

Mercury or quickſilver.

Iron is diſſolved by tin in a heat far leſs than that in which iron itſelf melts; the compound is white and brittle. Iron added to a mixture of lead and tin, takes up the tin, leaving the lead at the bottom; and in like manner, if lead, tin, and ſilver, are melted together, the addition of iron will abſorb all the tin, and the tin only. Hence an eaſy method of purifying ſilver from tin.

1222 Injurious to other metals.

1223 Not liable to ruſt.

Tin notwithſtanding it is, like lead, ſoon deprived of its luſtre by expoſure to the air, is nevertheleſs much leſs liable to ruſt than either iron, copper, or lead; and hence is advantageouſly uſed for covering over the inſides of other metalline veſſels. The amalgam of mercury and tin is employed to cover one of the ſurfaces of looking-glaſſes; by which they are rendered capable of reflecting the rays of light. The amalgam alſo, mixed with ſulphur and ſal ammoniac, and ſet to ſublime, yields a ſparkling gold-coloured ſubſtance called *aurum moſaicum*; which is ſometimes uſed as a pigment. This preparation is commonly made from quickſilver and tin, of each two parts, amalgamated together; and then thoroughly mixed with ſulphur and ſal ammoniac, of each one part and a half. The mercury and ſulphur unite into a cinnabar, which ſublimes along with the ſal ammoniac; and, after ſublimation, the aurum moſaicum remains at the bottom.

1224 Aurum moſaicum.

Sulphur may be united with tin by fuſion; and forms with it a brittle maſs, more difficultly fuſible than pure tin. Sulphur has, in this reſpect, the ſame effect upon tin as upon lead. The allay of tin leſſens the fuſibility of theſe very fuſible metals, while it increaſes the fuſibility of other difficultly fuſible metals, as iron and copper.

§ 7. *MERCURY or QUICKSILVER.*

MERCURY is a fluid metallic ſubſtance, of a bright ſilver colour, reſembling lead or tin when melted; entirely void of taſte and ſmell; extremely diviſible; and congealable only in a degree of cold very difficultly produced, in this country, by art (ſee COLD and CONGELATION). It is the moſt ponderous of all fluids, and of all known bodies, gold and platina excepted; its ſpecific gravity being to that of water nearly as 14 to 1. It is found to be ſpecifically heavier in winter than in ſummer by 25 grains in 11 ounces

1225 Heavier in winter than in ſummer.

Neither air nor water, nor the united action of theſe two, ſeem to make any impreſſion upon mercury: nor is it more ſuſceptible of ruſt than the perfect metals. Its ſurface, nevertheleſs, is more quickly tarniſhed than gold or ſilver; becauſe the duſt which floats in the air, quickly ſeizes on its ſurface. The watery vapours alſo, which float in the air, ſeem to be attracted by mercury.

1226 Purification.

From theſe extraneous matters, which only ſlightly adhere to it, mercury may be eaſily cleanſed by paſſing it through a clean new cloth, and afterwards heating it: but if mixed with any other metal, no ſeparation can be effected without diſtillation. In this proceſs, a ſmall portion of ſome of the metals generally ariſes along with the mercury. Thus, quickſilver

Mercury or quickſilver.

ver diſtilled from lead, biſmuth, or tin, appears leſs bright than before; ſtains paper black; ſometimes exhibits a ſkin upon the ſurface; and does not run freely, or into round globules. Mr Boyle relates, that he has obſerved the weight of mercury ſenſibly increaſed by diſtillation from lead, and this when even a very moderate fire was made uſe of. By amalgamation with ſtellated regulus of antimony, and then being diſtilled after a few hours digeſtion, mercury is ſaid to

1227 Curious mercuries by Boyle.

become, by a few repetitions of the proceſs, more ponderous, and more active. The animated, or philoſophic mercuries of ſome of the alchemiſts, are ſuppoſed to have been mercury thus prepared. By the ſame, or ſimilar proceſſes, ſeem to have been obtained the curious mercuries which Boyle declared he was poſſeſſed of, and made himſelf; which were "conſiderably heavier in ſpecie than common quickſilver,—diſſolved gold more readily,—grew hot with gold, ſo as to be offenſive to the hand, and elevated gold in diſtillation." When quickſilver is to be diſtilled, it is proper to mingle it with a quantity of iron-filings; which have the property of making it much brighter than it can be otherwiſe obtained, probably by furniſhing phlogiſton.

By digeſtion in a ſtrong heat for ſeveral months, mercury undergoes a conſiderable alteration, changing into a powder, at firſt aſh-coloured, afterwards yellow, at length of a bright red colour, and an acrid

1228 Mercurius precipitatus per ſe.

taſte; and is then called *mercurius precipitatus per ſe*. In this laſt ſtate it proves ſimilar to the red precipitate, prepared from a ſolution of mercury in nitrous acid. This calx proves leſs volatile in the fire than the mercury in its fluid ſtate. It ſupports for ſome time even a degree of red heat. In the focus of a burning mirror, it is ſaid to melt into glaſs when laid upon a piece of charcoal, and to revive into running mercury before it exhales. Evaporated by common fire, it leaves a ſmall portion of a light brown powder; which, Boerhaave relates, bore a blaſt-heat; ſwelled into a ſpongy maſs; formed with borax a vitreous friable ſubſtance; but vaniſhed in cupellation.

1229 Mercury unalterable by a gentle heat;

By a long continued digeſtion in a gentle heat, mercury ſuffers little change. Boerhaave digeſted it in low degrees of heat, both in open and cloſe veſſels, for 15 years together, without obtaining any other reward for his labour than a ſmall quantity of black powder; which, by trituration, was quickly revived into running mercury. Conſtant triture, or agitation, produce a change ſimilar to this in a ſhort time. Both the black and red powders, by bare expoſure to a fire ſufficient to elevate them, return into fluid mercury. The red powder has been revived by ſimply grinding it in a glaſs mortar.

1230 Or by diſtillation.

In like manner, quickſilver remains unchanged by diſtillation. Boerhaave had the patience to diſtil 18 ounces of mercury upwards of 500 times over, without obſerving any other change than that its fluidity and ſpecific gravity were a little increaſed, and that

1231 Exploſion by the vapours of mercury.

ſome grains of a fixed matter remained. The vapours of mercury, like thoſe of all other volatile bodies, cauſe violent exploſions if confined. Mr Hellot gives an account of his being preſent at an experiment of this kind: a perſon pretending to fix mercury, had incloſed it in an iron box cloſely welded. When the mercury was heated, it burſt the box, and diſſipated in inviſible vapours.

1232 Amalgamated with different ſubſtances.

Mercury diſſolves or unites with all metallic bodies, except three, *viz.* iron, arſenic, and nickel: in ſome caſes it will abſorb metals, particularly gold and ſilver, from their ſolutions in acids or alkalies; but does not act upon any metal when combined with ſulphur, nor on precipitates made by alkalies, nor on calces by fire. Whatever metal it is united with, it conſtantly preſerves its own white colour. It unites with any proportion of thoſe metallic ſubſtances with which it is capable of being combined; forming, with different quantities, amalgams of different degrees of conſiſtence. From the fluid ones, greateſt part of the quickſilver may be ſeparated by colature. Biſmuth is ſo far attenuated by mercury, as to paſs through leather with it in conſiderable quantity. It alſo promotes the action of quickſilver upon lead to a great degree; ſo that mercury united with $\frac{1}{4}$, $\frac{1}{8}$, or $\frac{1}{12}$ its weight of biſmuth, diſſolves maſſes of lead in a gentle warmth, without the agitation, triture, comminution, or melting heat neceſſary to unite pure mercury with lead. From theſe properties, this ſolution of biſmuth in mercury becomes a proper ſolvent for pieces of lead lodged in the human body.

1233 Separation of the amalgamated metal.

On triturating or digeſting amalgams for a length of time, a blackiſh or duſky coloured powder ariſes to the ſurface, and may be readily waſhed off by water. Some of the chemiſts have imagined, that the amalgamated metal was here reduced to its conſtituent parts: but pure mercury is by itſelf reducible to a powder of the ſame kind; and the metallic particles in this proceſs, united with the mercury, are found to be no other than the metal in its entire ſubſtance. Some metals ſeparate more difficultly than others; gold and ſilver the moſt ſo. Boerhaave relates, that if the powder which ſeparates from an amalgam of lead be committed to diſtillation with vinegar in a tall veſſel, the mercury will ariſe before the vinegar boils; that, by a like artifice, quickſilver may be made to diſtil in a leſs degree of heat than that of the human body: but Dr Lewis, though he made many trials, was never able to ſucceed.

1234 Becomes fixed by amalgamation with gold.

By amalgamation with gold, mercury may become exceedingly fixed; ſo as not to be diſſipable by the greateſt heat. Concerning this, Dr Brandt relates the following curious experiment: "Having amalgamated fine gold with a large proportion of quickſilver, and ſtrained off the ſuperfluous mercury, he digeſted the amalgam in a cloſe ſtopped veſſel for two months with ſuch a degree of heat, that a part of the quickſilver ſublimed into the neck of the glaſs. The matter being then ground with twice its weight of ſulphur, and urged with a gradual fire in a crucible, a ſpongy calx remained; which being melted with borax, and afterwards kept in fuſion by itſelf for half an hour, in a very violent fire, ſtill retained ſo much of the quickſilver as to become brittle under the hammer, and appear internally of a leaden colour. The metal being again amalgamated with freſh mercury, the amalgam again ground with ſulphur, and expoſed to an intenſe fire, a ſpongy calx remained as before. This calx being digeſted in two or three freſh parcels of aqua-regia, a ſmall portion of whitiſh matter remain-

ed

Mercury or quicksilver.

ed at last undissolved. The paper which covered the cylindrical glass wherein the digestion was performed, contracted, from the vapours, a deep-green circular spot in the middle, with a smaller one at the side; whereas the aqua-regia digested in the same manner by itself, or with gold, or with mercury, gave no stain. The first solution, on the addition of oil of tartar *per deliquium*, grew red as blood; on standing, it deposited, first, a little yellow calx, like aurum fulminans; afterwards, a bright matter like fine gold; and at last, a paler precipitate, inclining to green; its own deep red colour and transparency remaining unchanged. Being now committed to distillation, a colourless liquor arose; and the residuum, perfectly exsiccated, yielded, on edulcoration, a yellow calx of gold; which the alakaline lixivium had been unable to precipitate. The second solution turned green on the admixture of the alkaline liquor, and let fall a white precipitate, which turned black and brown. The several precipitates were calcined with twice their weight of sulphur, and then melted with four times their quantity of flint, and twelve of pot-ash, in a fire vehemently excited by bellows. The scoria appeared of a golden colour, which, on pulverization and edulcoration, vanished. At the bottom was a regulus, which looked bright like the purest gold; but was not perfectly malleable. Broken, it appeared internally white; and the white part amounted to at least one-third its bulk Besides this lump of metal, there were several others, white like silver, and soft as lead."

1235 **Supposed to be convertible into water.**

In Wilson's chemistry, we have a process for converting quicksilver into water, by dropping it by little and little into a tall iron vessel, heated almost to a white heat in the bottom. Over the mouth of this vessel were luted seven aludels; and on the top, a glass alembic head, with a beak, to which was fitted a receiver. The mercury was put in so slowly, that it required 16 hours for one pound. Every time that a little quantity of mercury was put in, it made a great noise, filling the aludel's head and receiver with white fumes. When the vessels were cooled, a little water was found in each of the receivers, and in the first and second some grains of crude mercury. The whole quantity amounted to 13 ounces and 6 drachms; which was expected to prove a powerful solvent of gold and silver: but, on trial, was found to be in no respect different from common water. On this experiment Dr Lewis has the following note.

1236 **Dr Lewis's detection of the falsehood of this process.**

" The possibility of converting mercury into water, or at least of obtaining a great quantity of water from mercury, has not only been believed by several great men in the chemical art, but some have even ventured to assert that they have actually made this change. Yet, nevertheless, they have delivered the history of this affair with such marks, as seem to make the reality of the change extremely doubtful. Mr Boyle (in his tract *of the producibleness of Chemical Principles*, annexed to *Scept. Chemist.* p. 235) says, " that he once obtained water from mercury without additament, without being able to make the like experiment succeed afterwards." M. Le Feburc, who is generally looked upon as an honest practitioner, directs a process similar to that above (Wilson's), for obtaining of this mercurial water. But it is to be suspected, as Mr Hales very well observes (in his *Statical Experiments*, p. 200.), that Mr Boyle and others were deceived by some unheeded circumstance, when they thought they obtained a water from mercury, which should seem rather to have arisen from the lute and earthen vessels made use of in the distillation: for Mr Hales could not find the least sign of any moisture upon distilling mercury in a retort made of an iron gun-barrel, with an intense degree of heat; although he frequently cohobated the mercury which came over into the recipient. " In a course of chemical experiments, I repeated Mr Hales's process, and urged the mercury, which was let fall by little and little, through an aperture made in the gun-barrel, with a most intense degree of heat, without obtaining any water; but it being suspected by a bystander, that the mercury in this experiment came over before it had been sufficiently acted upon by the fire, by reason of the lowness of the neck of the distilling instrument, the experiment was varied in the following manner. Sixteen ounces of mercury were heated in a crucible, in order to evaporate any moisture that might have been accidentally mixed with it; and an iron gun-barrel of four feet in length, being placed perpendicularly in a good furnace, and a glass-head and recipient fitted to its upper part, the mercury was let fall by little and little into the barrel, and the fire urged with bellows. After each injection, the mercury made a considerable noise and ebullition, and arose into the head; where it soon condensed and trickled down, in the common form of running mercury, into the recipient, without the least perceptible appearance of any aqueous humidity."

1237 **How to amalgate with regulus of antimony.**

Mercury is difficultly amalgamated with regulus of antimony and copper; for which some particular manœuvres are required. Two of Dr Lewis's receipts for uniting quicksilver with copper, we have already given (n° 1153.): with regulus of antimony, mercury, he says, may be perfectly united, by pouring a small stream of melted regulus into a considerable portion of mercury, made almost boiling hot. Another method directed by Henckel, is to put mercury into an iron mortar along with some water, and set the whole over the fire. When the water boils, a third or fourth part of melted regulus is to be poured in, and the mass ground with a pestle, till the amalgam is completed. The use of the water, as Dr Lewis observes, is to hinder the mercury from flying off by the heat of the regulus: but as the two are by this means not put together in so hot a state, the union is more difficult, and less perfect. The loss of the mercury, in the first process, may be prevented by using a large vessel, and covering it with a perforated iron-plate, through the hole in which the regulus is to be poured. This method is likewise applicable to the amalgamation of copper.

With sulphur, mercury unites very readily, forming by trituration, or simple fusion, a black powder or mass, called *Ethiops mineral*; which, by careful sublimation, becomes the beautiful red pigment called *vermillion*. (See SULPHUR, sect. iv.).

1238 **Preparations of mercurius dulcis in the moist way.**

The extensive use of mercurius dulcis in medicine has rendered it an object to chemists to find out some method of preparing it with less expence and trouble, and with more certainty of its effects, than it can be by the methods hitherto mentioned. This is now accomplished

Mercury of quickſilver.

pliſhed through the induſtry of Mr Scheele, to whom chemiſtry in general has been ſo much obliged. His method is as follows:

"Take half a pound of quickſilver, and as much pure common aquafortis. Pour it into a ſmall cucurbit with a pretty long neck, ſtop the mouth with a little paper, and put it into warm ſand. Some hours afterwards, when the acid appears no longer to act upon the quickſilver, the fire is to be augmented ſo as to make the ſolution nearly boil. This heat is to be continued for three or four hours, and the veſſel now and then to be ſhaken. Towards the end, regulate the heat in ſuch a manner that the ſolution ſhall gently boil for a quarter of an hour. In the mean time, diſſolve $4\frac{1}{2}$ ounces of pure common ſalt in ſix or eight pounds of water; pour this ſolution, ſtill boiling, into a glaſs veſſel, and immediately afterwards mix with it the abovementioned ſolution of quickſilver, which alſo muſt be boiling, in ſmall quantities at a time, with conſtant agitation. When the precipitate has ſettled, decant off the clear liquor, and pour hot water again on the precipitate, with which it is to be edulcorated till the water ſtanding upon it ſhall be entirely taſteleſs. Put the whole, obtained by theſe means, together, filter and dry it in a mild heat."

1239 How to obtain a perfectly ſaturated ſolution of quickſilver.

On this proceſs it is remarked, that when the quickſilver no longer effervesces with the acid, one would imagine that a ſaturation had taken place. But this is far from being the caſe. By increaſing the heat the ſolution is ſtill able to diſſolve a great quantity; with this difference, however, that, whereas the quickſilver in the beginning is calcined, a great deal of it afterwards, in a metallic form, is diſſolved, as appears from this, that not only no more elaſtic vapours aſcend; but alſo, that with fixed and volatile cauſtic alkalies, a black precipitate is obtained; otherwiſe, when the ſolution contains only calcined quickſilver, the precipitate is yellow. If the black precipitate be gently diſtilled, quickſilver ariſes, and there remains a yellow powder, which is that part of the metal that was calcined by the nitrous acid. The fire muſt at any rate be augmented, in order to keep the mercurial calx diſſolved, the compound of this metal and nitrous acid being extremely apt to cryſtallize even in the heat. There commonly remains ſome undiſſolved quickſilver; but it is always better to take too much than too little; for the more metal the mercurial ſolution contains, the more mercurius dulcis is obtained at laſt. The quantity here mentioned uſually produces $8\frac{1}{2}$ ounces of mercurius dulcis. The mercurial ſolution muſt be cautiouſly poured into that of ſea-ſalt, that no mercury may follow. Two ounces of ſalt would be ſufficient for the precipitation of all the quickſilver; but when ſo ſmall a quantity is uſed, it may eaſily happen, that ſome ſuperabundant corroſive ſublimate may adhere to the precipitate, which water alone is incapable of entirely ſeparating. Among other advantages this method of making mercurius dulcis poſſeſſes, it is none of the leaſt, that the powder is much finer than any to which it can be reduced in the common way by trituration, however long continued.

§ 8. *Zinc.*

Zinc.

This is a ſemimetal of a bluiſh white colour. It is the leaſt brittle of any of the ſemimetals; and when amply ſupplied with phlogiſton, which may be done by treating it in cloſe veſſels with inflammable matters, it poſſeſſes a ſemiductility, by which it may be flattened into thin plates. When broken, it appears formed of many flat ſhining plates or facets, which are larger when ſlowly than when haſtily cooled. When heated, it is very brittle; and crackles like tin, only louder, when bent. Expoſed to the air, it contracts in length of time a yellowiſh ruſt. Its ſpecific gravity, according to Dr Lewis, is to that of water as $7\frac{1}{10}$ to 1. It begins to melt as ſoon as red-hot; but does not flow thin till the fire is raiſed to a white heat. Then

1240 Deflagration.

the zinc immediately begins to burn with an exceedingly bright and beautiful flame. Kept juſt in fuſion, it calcines ſlowly; not only on the upper ſurface, but likewiſe round the ſides, and at the bottom of the crucible. If ſeveral pieces are juſt melted together, the maſs, when grown cold, may be broken into the ſame number; their union being prevented by a yellowiſh calx, with which each piece is covered over. M. Malouin relates, in the French Memoirs for 1742, that a quantity of zinc being melted ſix times, and the fuſion continued fifteen hours each time, it proved, on every repetition, harder, more brittle, leſs fuſible, and leſs calcinable; that after the two firſt fuſions, its colour was grey; after the third, brown; and after the fourth, black; that the fifth rendered it of a ſlate-blue; and the ſixth of a clear violet.

1241 Flowers of zinc.

So violent is the deflagration of zinc, that the whole of its calx is ſublimed by it, in the form of light flocks of wool; which, however, are eaſily reduced to a fine powder. Theſe are uſed in medicine, and reckoned an excellent remedy in epileptic caſes. When once ſublimed, they are by no means capable of being elevated again by the moſt violent heat. In a heat far greater than that in which they firſt aroſe, they ſuffer no alteration; in a very vehement one, they melt, according to Henckel, into a ſemiopaque green glaſs. Vitrified with borax, they give a grey, or browniſh, glaſs. From the brightneſs of the flame of burning zinc, and the garlic ſmell which it is ſaid to emit, ſome have concluded that zinc contained the phoſphorine acid; which, from ſome other circumſtances, is not altogether improbable.

1242 Dr Lewis's method of reducing them.

The flowers of zinc have been thought very difficultly, or not at all, reducible to their metallic form by an addition of phlogiſton. But Dr Lewis obſerves, that this difficulty proceeds not from their unfitneſs to be reſtored into the form of zinc, but from the volatility of the ſemimetal, which occaſions its being diſſipated in fumes, if the common methods are made uſe of. All calces, theſe of iron excepted, require a greater heat for their fuſion than that in which the metal itſelf melts; and as a full melting heat is the greateſt that zinc can ſuſtain, it burns and calcines the inſtant of its revival, if the air is admitted; and in cloſe veſſels eſcapes, in part at leaſt, through their pores. On mixing flowers of zinc with powdered charcoal, and urging them with a ſtrong fire in a crucible, a deflagration and freſh ſublimation enſue: ſufficient marks that the zinc has been reduced to its metallic form; for as long as it remains in the ſtate of calx, neither of theſe effects can happen. If the veſſel is ſo contrived

trived as to exclude the air, and at the same time to allow the reviving semimetal to run off from the vehemence of the heat, into a receiver kept cool, the zinc will there concrete, and be preserved in its metallic state. It is still more effectually detained by certain metallic bodies, as copper, or iron; with which the zinc, when thus applied, unites more readily and perfectly than it can be made to do by any other means.

1243 Oil from flowers of zinc by Mr Homberg.

Homberg pretended to obtain an oil from the flowers of zinc, by dissolving them in distilled vinegar, and then distilling the solution in a glass retort. At first a quantity of phlegm arose; then the superfluous acid; and at last an empyreumatic oil. This last, which Homberg imagined to proceed from the flowers of zinc, Newmann very justly attributes to the distilled vinegar.

1244 Another by Mr Hellot.

An oil of another kind was obtained by Mr Hellot from the above solution, by digesting the ash-coloured residuum, which remained after the distillation, with the acidulous phlegm which came over, for eight or ten days; distilling the tincture to dryness; and repeating the extraction with the distilled liquor, till the quantity of dry extract thus obtained was very considerable. This resin-like matter, distilled in a retort with a stronger fire, yielded a yellowish liquor, and a white sublimate. The liquor discovered no mark of oil; but, upon being passed upon the sublimate, immediately dissolved it, and then exhibited on the surface several drops of a reddish oil. Some of this oil was taken up on the point of a pencil, and applied to gold and silver-leaf. In twenty-four hours the parts touched appeared, in both, equally dissolved.

1245 Zinc with other metals.

Zinc does not unite in fusion with bismuth, or the semimetal called *nickel*. It unites difficultly with iron; less so with copper; easier with the other metals. It renders iron or copper more easily fusible; and, like itself, brittle whilst hot, though considerably malleable when cold. It brightens the colour of iron almost into a silver hue, and changes that of copper into a yellow or gold colour. It greatly debases the colour of gold; and renders near an hundredth part of that most ductile metal brittle and untractable. A mixture of equal parts of each is very hard, white, and bears a fine polish; hence it is proposed by Mr Hellot for making specula. It is not subject to rust or tarnish in the air, like those metals whose basis is copper. It improves the colour and lustre of lead and tin, renders them firmer, and consequently fitter for several mechanic uses. Tin, with a small proportion of zinc, forms a kind of pewter. Lead will bear an equal weight, without losing too much of its malleability. Maoluin observes, that arsenic, which whitens all other metals, renders zinc black and friable; that when the mixture is performed in close vessels, an agreeable aromatic odour is perceived on opening them; that zinc amalgamated with mercury, and afterwards recovered, proves whiter, harder and more brittle than before, and no longer crackles on being bent.

1246 Materials for specula.

1247 Deflagration of zinc with other metals.

Mixtures of zinc with other metals, exposed to a strong fire, boil and deflagrate more violently than zinc by itself. Some globules of the mixture are usually thrown off during the ebullition, and some part of the metal calcined and volatilized by the burning zinc: hence this substance has been called *metallic nitre*. Gold itself does not entirely resist its action. It very difficultly volatilizes copper; and hence the sublimates obtained in the furnaces where brass is made, or mixtures of copper and zinc melted, are rarely found to participate of that metal. On melting copper and zinc separately, and then pouring them together, a violent detonation immediately ensues, and above half the mixture is thrown about in globules.

1248 Cannot be united with sulphur.

Zinc does not unite in the least with sulphur, or with crude antimony, which scorify all other substances except gold and platina; nor with compositions of sulphur and fixed alkaline salts, which dissolve gold itself. With nitre it deflagrates violently. Its flowers do not sensibly deflagrate; yet alkalize double their weight of the salt more readily than the zinc itself. The alkaline mass appears externally greenish, internally of a purple colour. It communicates a fine purple to water, and a red to vinegar. The acetous tincture inspissated, leaves a tenacious substance which soon runs in the air into a dark red caustic liquor, the alkahest of some of the pretended adepts.

1249 Nitre alkalized by flowers of zinc.

§ 9. *Bismuth*.

This semimetal, called, also *tin-glass*, and by some naturalists *marcasita officinarum*, is somewhat similar to the regulus of antimony. It appears to be composed of cubes formed by the application of plates upon each other. Its colour is less white than that of regulus of antimony; and has a reddish tinge, particularly when it is exposed to the air. In specific gravity it approaches to silver; being nearly ten times heavier than water. It has no degree of malleability; breaking under the hammer, and being reducible by trituration to fine powder. It melts a little later than tin, and seems to flow the thinnest of all metallic substances. Bismuth is semivolatile, like all other semimetals. When exposed to the fire, flowers rise from it; it is calcined; and converted into a litharge and glass nearly as lead is; (See Glass). It may even be employed, like that metal, in the purification of gold and silver by cupellation. (See Refining). When in fusion, it occupies less volume than in its solid state: a property peculiar to iron among the metals, and bismuth among the semimetals. It emits fumes in the fire as long as it preserves its metallic form; when calcined or vitrified, it proves perfectly fixed.

1250 Convertible into litharge and glass.

1251 Promotes the fusion of all the metals,

Bismuth mingles in fusion with all the metalline substances, except regulus of cobalt and zinc. The addition of nickel or regulus of antimony, renders it miscible with the former, though not with the latter. It greatly promotes the tenuity as well as facility of the fusion of all those metals with which it unites. It whitens copper and gold, and improves the colour of some of the white metals: mixed in considerable quantity; it renders them all brittle, and of a flaky structure like its own. If mixed with gold or silver, a heat that is but just sufficient to melt the mixture, will presently vitrify a part of the bismuth; which, having then no action on those perfect metals, separates, and glazes the crucible all round.

§ 10. *Regulus of Antimony*.

THIS ſemimetal, when pure, and well fuſed, is of
1252 Appearance of a ſtar on its ſurface. a white ſhining colour, and conſiſts of laminæ applied to each other. When it has been well melted, and not too haſtily cooled, and its ſurface is not touched by any hard body during the cooling, it exhibits the perfect figure of a ſtar, conſiſting of many radii iſſuing from a centre. This proceeds from the diſpoſition that the parts of this ſemimetal have to arrange themſelves in a regular manner, and is ſimilar to the cryſtallization of ſalts.

Regulus of antimony is moderately hard; but, like other ſemimetals, it has no ductility, and breaks in ſmall pieces under a hammer. It loſes $\frac{1}{7}$ of its weight in water. The action of air and water deſtroys its luſtre, but does not ruſt it ſo effectually as iron or copper. It is fuſible with a heat ſufficient to make it red
1253 Sublimable. hot; but when heated to a certain degree, it fumes continually, and is diſſipated in vapours. Theſe fumes form what are called the *argentine flowers* of regulus of antimony, and are nothing but the earth of this ſemimetal deprived of part of its inflammable principle, and capable of being reduced to its reguline ſtate by an union with this principle.

1254 Separation of the ſulphur from antimony. There are different methods of preparing the regulus of antimony; but all of them conſiſt merely in ſeparating the ſulphur which this mineral contains, and which is united with the regulus. It is plain, therefore, that regulus of antimony may be made by an addition of any ſubſtance to crude antimony in fuſion, which has a greater attraction for ſulphur than the regulus itſelf has. For this purpoſe, alkaline ſalts have been employed, either previouſly prepared, or extemporaneouſly produced in the proceſs, by a deflagration of tartar and nitre. By this means, the ſulphur was indeed abſorbed; but the hepar ſulphuris, formed by the union of the ſulphur and alkali, immediately diſſolved the regulus, ſo that very little, ſometimes none at all, was to be obtained diſtinct from the ſcoria. Metals are found to anſwer better than alkaline ſalts, but the regulus is ſeldom or never free from a mixture of the metal employed. The way of obtaining a very pure regulus, and in great quantity, is to calcine the antimony in order to diſſipate its ſulphur; then to mix the calx with inflammable matters, ſuch as oil, ſoft ſoap, &c. which are capable of reſtoring the principle of inflammability to it. This method was invented by Kunckel. Another, but more expenſive way of procuring a large yield of very pure regulus, is, by digeſting antimony in aqua-regis, which diſſolves the reguline part, leaving the ſulphur untouched, precipitating the ſolution, and afterwards reviving the
1255 precipitate by melting it with inflammable matters.

Regulus eaſily miſcible with mercury. There are conſiderable differences obſerved in the regulus of antimony, according to the different ſubſtances made uſe of to abſorb the ſulphur. When prepared by the common methods, it is found to be very difficultly amalgamated with mercury; but Mr Pott has diſcovered, that a regulus prepared with two or five parts of iron, four of antimony, and one of chalk, readily unites with mercury into an hard amalgam, by bare trituration with water. Marble and quicklime ſucceed equally well with chalk; but clay, gypſum, or other earths, have no effect.

One earthy ſubſtance, found in lead-mines, and commonly called *cawk*, has a very remarkable effect upon antimony. This is found in whitiſh, moderately compact and ponderous maſſes; it is commonly ſuppoſed a ſpar; but differs from bodies of this kind, in not being acted upon by acids, (ſee n° 1068). If a lump of cawk, of an ounce or two, be thrown red hot into 16 ounces of melted antimony, the fuſion continued about two minutes, and the fluid matter poured off, "you will have 15 ounces like poliſhed ſteel, and as the moſt refined quickſilver." *Phil. Tranſ.* n° 110. Dr Lewis mentions his having repeated this experiment ſeveral times with ſucceſs: but having once varied it by mixing the cawk and antimony together at the firſt, a part of the antimony was converted into a very dark black vitreous matter, and part ſeemed to have ſuffered little change; on the ſurface of the maſs ſome yellow flowers appeared. 1256 Extemporaneous regulus with cawk.

Regulus of antimony enters into the compoſitions for metallic ſpeculums for teleſcopes, and for printing-types. It is alſo the baſis of a number of medicinal preparations; but many of theſe, which were formerly much eſteemed, are found to be either inert, uncertain, or dangerous in their operations. When taken in ſubſtance, it is emetic and purgative, but uncertain in its operation; becauſe it only acts in proportion to the quantity of ſolvent matter it meets with in the ſtomach; and if it meets with nothing capable of acting upon it there, the regulus will be quite inactive. For theſe reaſons, the only two preparations of antimony now retained, at leaſt by ſkilful practitioners, are the infuſion of glaſs of antimony in wine and emetic tartar. For making the glaſs of antimony we have the following proceſs. "Take a pound of antimony; reduce it to fine powder, and ſet it over a gentle fire; calcine it in an unglazed earthen pan, till it comes to be of an aſh colour, and ceaſes to fume: you muſt keep it continually ſtirring; and if it ſhould run into lumps, you muſt powder them again, and then proceed to finiſh the calcination. When that is done, put the calcined antimony into a crucible; ſet it upon a tile in a wind-furnace; put a thin tile on the top; and cover it all over with coals. When it is brought into fuſion, keep it ſo in a ſtrong fire for an hour: then put into it an iron rod; and when the melted antimony, which adheres to it, is tranſparent, pour it upon a ſmooth, hot, marble; and when it is cold, put it up for uſe. This is *vitrum antimonii*, or *ſtibium*." 1257 Glaſs of antimony.

This preparation is more violent in its effects than the pure regulus itſelf; becauſe it contains leſs phlogiſton, conſequently is ſimilar to a regulus partially calcined, and ſo more ſoluble. Hence it is the moſt proper for infuſion in wine, or for making the tartar emetic. It is obviouſly, however, liable to great uncertainties in point of ſtrength; for as the antimony is more or leſs ſtrongly calcined, the glaſs will turn out ſtronger or weaker in its operation, and conſequently all the preparations of it muſt be liable to much uncertainty. This uncertainty is very apparent in the ſtrength of different parcels of emetic tartar: accordingly Mr Geoffroy found by examination of different emetic tartars, that an ounce of the weakeſt contain- 1258 Difference of ſtrength in emetic tartars.

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Regulus of antimony. ed from 30 to 90 grains of regulus; an ounce of moderate strength contained about 108 grains; and an ounce of the strongest kind contained 154 grains. For these reasons, the author of the Chemical Dictionary recommends the pulvis algaroth as the most proper material for making emetic tartar; being per-
1259 Pulvis algaroth the most proper material for emetic tartar. fectly soluble, and always of an equal degree of strength. Emetic tartar, as he justly observes, ought to be a metallic salt composed of cream of tartar saturated with the regulus of antimony; and M. Beaumé has shown such a saturation to be possible, and that the neutral salt crystallizes in the form of pyramids. They are transparent while moist; but by exposure to a dry air, they lose the water of their crystallization and become opaque. The preparation of this salt, according to M. Baumé, consists in mixing together equal parts of cream of tartar, and levigated glass of antimony: these are to be thrown gradually into boiling water; and the boiling continued till there is no longer any effervescence, and the acid is entirely saturated. The liquor is to be filtered; and upon the filter is observed a certain quantity of sulphureous matter along with some undissolved parts of the glass of antimony. When the filtered liquor is cooled, fine crystals will be formed in it, which are a soluble tartar perfectly saturated with glass of antimony. He observes, that the dissolution is soon over if the glass is well levigated, but re-
1260 quires a long time if it is only grossly pounded.

Objection to its use. The trouble of levigating glass of antimony, as well as the uncertainty of dissolving it, would render *pulvis algaroth* much preferable, were it not on account of its price; which would be a temptation to those
1261 in use to prepare medicines, to substitute a cheaper
Scheele's theory of the nature of pulvis algaroth. antimonial preparation in its place. This objection, however, is now in a great measure removed by Mr Scheele; who demonstrated that the pulvis algaroth is no other than regulus of antimony half calcined by the dephlogisticated marine acid in the corrosive sublimate made use of for preparing the antimonial caustic. If therefore we can fall upon any other method of dephlogisticating the regulus, we shall then be able to combine the marine acid with it; and by separating them afterwards, may have the powder of algaroth as good as from the butter of antimony itself. One of the methods of dephlogisticating the regulus is by nitre. Our author therefore gives the following receipt for the powder in question.

1262 His receipt for making it cheap. "Take of powdered crude antimony one pound; powdered nitre, one pound and a half; which, after being well dried and mixed, are to be detonated in an iron mortar. The hepar obtained in this manner is to be powdered, and a pound of it to be put into a glass vessel, on which first a mixture of three pounds of water and 15 ounces of vitriolic acid is to be poured, and afterwards 15 ounces of powdered common salt are to be added; the glass vessel is then to be put in a sand-bath, and kept in digestion for 12 hours, during which period the mass is to be constantly stirred. The solution, when cool, is to be strained through linen. On the residuum one third of the above menstruum is to be poured, and the mixture digested and strained. From this solution, when it is diluted with boiling water, the pulvis algarothi precipitates, which is to be well edulcorated and dried."

As regulus of antimony, like other metallic substances, is soluble in liver of sulphur, it happens, that, on boiling antimony in an alkaline ley, the salt, uniting with the sulphur contained in that mineral, forms an hepar sulphuris, which dissolves some of the reguline part. If the liquor is filtered, and saturated with an acid, the regulus and sulphur will fall together in form of a yellowish or reddish powder, called *golden sulphur of antimony*. If the ley is suffered to cool, a like precipitation of a red powder happens. This last is called *kermes mineral*. 1263 Golden sulphur of antimony and kermes mineral.

1263 Diaphoretic antimony. Nitre deflagrates violently with antimony, consuming not only its sulphureous part, but also the phlogiston of the regulus: and thus reduces the whole to an inert calx, called *antimonium diaphoreticum*. If equal parts of nitre and antimony are deflagrated together, the sulphureous part is consumed, as well as part of the inflammable principle of the regulus. The metalline part melts, and forms a semivitreous mass of reddish colour, called *crocus metallorum*, or *liver of antimony*. It is a violent emetic, and was formerly used for making infusions in wine similar to those of glass of antimony; but is now disused on account of its uncertainty in strength. It is still used by the farriers: but the substance sold for it is prepared with a far less proportion of nitre; and sometimes even without any alkaline salt being added to absorb part of the antimonial sulphur. This crocus is of a dull red colour; and, when powdered, assumes a dark purple. 1265 Crocus metallorum.

§ II. *Arsenic.*

This substance, in its natural state, has no appearance of a metal, but much more resembles a salt, which, as has been already observed, it really is when deprived 1266
of its phlogiston. When united to a certain quantity of phlogiston, it assumes a metallic appearance; and in this state it is found, as Mr Bergman informs us, in Bohemia, Hungary, Saxony, Hercynia, and other parts; particularly at Alsatia in the mines called *St Marieux*. The masses in which it is found are frequently shapeless, friable, and powdery; but sometimes compact, and divided into thick convex lamellæ, with a needle-formed or micaceous surface: it takes a polish, but soon loses it again in the air. When fresh broken, it appears composed of small needle-like grains of a leaden colour, soon becoming yellow, and by degrees blackish; exceeding copper in hardness, though as brittle as antimony. 1267 Arsenic found naturally in a metallic form.

Reguline arsenic, whether found naturally or prepared by art, very readily parts with as much of its phlogiston as is sufficient to make it fly off in a white smoke; but this still retains a very considerable quantity of phlogistic matter, as is evident from its producing nitrous air by the affusion of nitrous acid, and from the experiments already related of the preparation of the acid of arsenic. This calx indeed is the form in which arsenic is most commonly met with. It is less volatile than the regulus; and by sublimation in a glass vessel assumes an opaque crystalline appearance from becoming white on the surface; but that which crystallizes in the bowels of the earth does not appear to be subject to any such change. 1268 Regulus of arsenic easily converted into the common white kind.

White arsenic, though a true metalline calx, may be mixed in fusion with the same metals which will unite with the regulus. This seems contrary to the general rule of other calces, which cannot be united with any metal White arsenic may be mixed with other metals.

Arsenic. metal in its metalline state; but it must be remembered, that by this operation the arsenical calx is reduced to a regulus by the phlogiston of the metal: whence, in all fusions of this kind, some scoriæ rise to the top, consisting of the calcined metal and part of the white arsenic.

1269 Solution of arsenic in water. Eight parts of distilled water dissolve, by means of moderate heat, one part of calcined arsenic, and by boiling may be made to take up 15. The solution changes syrup of violet green, but the tincture of turnsole red. It is not changed by neutral salts, but slowly precipitates the solutions of metals, the arsenic united to the metallic calx falling to the bottom.—"It may be asked (says Mr Bergman), whether the whole of the arsenic, or only the arsenical acid, unites with the metallic calx, yielding the phlogiston to the menstruum of the other metal?" Certainly such a mutual commutation of principles does not appear improbable, if we consider only those cases in which the menstruum is vitriolic or nitrous acid: but as iron, for example, united with marine acid (which does not attract the phlogiston of white arsenic), as well as when it is joined to the nitrous acid, is precipitated, it would appear that the whole of the arsenic is united, at least in certain cases, to the metallic calces.

1270 And in spirit of wine. One part of arsenic is dissolved by 70 or 80 of boiling spirit of wine.

1271 In vitriolic acid. Arsenic dissolves partially in concentrated vitriolic acid, but concretes in the form of crystalline grains on cooling. These dissolve in water with much greater difficulty than the arsenic itself. On the blow-pipe they emit a white smoke, but form into a globule by fusion, which at first bubbles, but soon grows quiet, and is but slowly consumed even in a white heat. This fixity is occasioned by the acid carrying off the phlogiston of the arsenic, and thus leaving a greater proportion of its peculiar acid than what it naturally contains; and therefore the more frequently the operation is repeated, the more fixed the arsenic becomes, though it is scarce possible to dissipate the arsenical phlogiston as perfectly with this acid as with the nitrous; the effects of which have been already particularly mentioned.

1272 In marine acid. The marine acid, which naturally contains phlogiston, dissolves about one-third of its weight of arsenic, a great part of which separates spontaneously on cooling in a state of saturation with the acid. This salt, which may be had in a crystalline form, is much more volatile than the former, readily subliming in a close vessel with a moderate heat; but is soluble with difficulty in boiling water. It is of a fine yellow colour, and scarcely differs from butter of arsenic, except in its degree of concentration. The nature of marine acid prevents it from disengaging the arsenical acid from the phlogiston of the semimetal, as will easily appear from what has been said concerning that acid. The arsenical acid, however, is easily made to appear by the addition of that of nitre, as will be understood from the directions given by Mr Scheele for the preparation of the acid of arsenic.

1273 Phlogisticated alkali cannot precipitate arsenic except from marine acid. Arsenic is not precipitated from its solution in vitriolic and nitrous acids by the phlogisticated alkali, which yet very readily precipitates all other metals. From the marine acid, however, it is precipitated by its means of a white colour; but unless the solution be very acid, the addition of mere water will throw down a precipitate of the same colour.

1274 Decomposed by dephlogisticated marine acid. Dephlogisticated marine acid deprives arsenic of its inflammable principle; so that in the distilling vessel we find water, acid of arsenic, and marine acid, regenerated.

1275 Phenomena with other acids. Arsenic is dissolved by its own acid, and forms crystalline grains with it as well as with that of fluor and borax. Saccharine acid dissolves it likewise, and forms prismatic crystals; and a similar salt is also formed by the acid of tartar. Vinegar, and the acids of vinegar and phosphorus, form with it crystalline grains, which are scarcely soluble in water.

1276 Liver of arsenic. Solutions of fixed alkali dissolve arsenic; and, when loaded with it, form a brown tenacious mass, called *liver of arsenic*. The arsenic is partly precipitated by mineral acids, though part of it gradually loses its phlogiston, and adheres more tenaciously. Solution made with volatile alkali seems to effect this decomposition more readily, as no precipitation is made by acids. Limpid solution of saline hepar, dropped into a solution of white arsenic, floats upon the surface in form of a grey stratum, which at length disturbs the whole liquor.

1277 Effects on metals. By the assistance of heat solutions of arsenic attack some of the metals, particularly copper, iron, and zinc; the solutions of the two last yielding crystals by evaporation. No alteration is made on these compounds by alkaline salts or by acids: volatile alkali does not discover the copper by changing the colour of the solution blue; nor does the phlogisticated alkali throw down any blue precipitate from the solution of iron. The reason of this is the superabundance of phlogiston in the solutions; for the arsenical acid takes up all metals: when united with copper, it shows a blue colour with volatile alkali; and when united with iron, it lets fall a Prussian blue in the usual way; but the quantity of phlogiston which converts the acid into white arsenic, prevents the appearance of these phenomena when the latter is made use of.

1278 Unites easily with sulphur. Arsenic, either in its calcined or reguline state, may be united with sulphur; in which case it appears either of a red or yellow colour, according to the quantity of sulphur with which it is united. These compounds are spontaneously produced by nature; both of them sometimes pellucid and crystalline; with this difference, however, that the yellow seems to affect a lamellated, and the red a crystalline, form.

1279 Realgar and orpiment. These are called *red and yellow orpiment*, or realgar and orpiment; the specific gravity of realgar being about 3.225; of orpiment, 5.315. Both of these sublime totally with a moderate heat, unless when they happen to be mixed with other substances. They readily unite with those metals which form an union with the arsenic and sulphur of which they are composed. Silver mineralized by fusion with orpiment, forms a substance similar to what is called the red ore of that metal. Iron, in conjunction with orpiment, assumes a white, polished, and metallic appearance, similar to that of the white or arsenical pyrites; and by various combinations of these substances with metals of different kinds, many of the natural metalline ores may be produced.

1280 Phenomena with nitrous acid. Nitre, when treated with mineralized arsenic, detonates

Arsenic. torates partly with the sulphur, and partly with the phlogiston of the arsenic; the alkaline basis of the salt either forming sal polychrest with the acid of the sulphur, or uniting with the alkali, and forming the neutral arsenical salt. By the addition of fixed alkali in proper quantity, either to orpiment or realgar, and then exposing the mixture to a subliming heat, nitre retains the sulphur, but lets go the greatest part of the arsenic; the hepatic mass, however, retains a small quantity of the latter; and if there is much alkali, scarce any of the arsenic arises.

1281 Butter of arsenic. On distilling orpiment with twice or thrice it quantity of corrosive sublimate, two liquids arise which refuse to unite; and at length, on augmenting the heat, a cinnabar arises. A butter of arsenic is found at the bottom of the receiver, of a ferruginous brown colour, but pellucid: in the open air it first sends forth a copious fume of a white colour, and then gradually attracts the moisture of the atmosphere, by which it is precipitated.

1282 Can scarce be made to unite with marine acid. It is remarkable that it unites so slowly with marine acid, that they seem to repel one another; nor can they be made to unite beyond a certain degree. By the affusion of distilled water, a white powder will be precipitated, which, though ever so well washed, retains some acidity; for a portion of butter of antimony is produced by distillation, as is likewise true of the pulvis algaroth. The smoke has a peculiar penetrating smell, somewhat similar to that of phlogisticated vitriolic acid, and lets fall white flowers.

1283 Oil of arsenic. The liquor which swims above, and which, by chemical authors, has been compared to oil, is yellowish and pellucid, separating a white arsenical powder by the addition of water and spirit of wine. It is not affected by the stronger acids; but effervesces, and lets fall a precipitate, with alkalies. On keeping it with a cucurbit with a long neck unstopped, white flowers gradually concrete round the orifice, which are lax, and sometimes approaching to a crystalline form. And lastly, by spontaneous evaporation, pellucid crystals appear at the bottom of the liquor, which are soluble in water with great difficulty; but when dissolved, precipitate silver from nitrous acid, and let fall some arsenic on the addition of an alkali. When put into lime-water, a cloud slowly surrounds them: on being exposed to the fire, they totally sublime without any arsenical smell, without decrepitation, or losing their transparency; but if ignited phlogistic matter comes in contact with them, the arsenical smell instantly appears. No traces of mercury are to be found in this liquor by treating it either with alkali or copper; nor the slightest precipitation is made by it on being dropped into a solution of terra ponderosa in the marine acid: from all which it appears, that this liquor is only a very dilute butter of arsenic, containing less of the mercury on account of the quantity of water it has. The butter contains the acid in its most concentrated state, and is therefore loaded with a larger quantity of arsenic: the former liquor will therefore be obtained in much larger quantity, by setting the mixture of corrosive sublimate and arsenic to stand a night in a cellar, or moistened with water, before it be subjected to distillation. As the common marine acid can dissolve only a determined quantity of the butter, it naturally follows, that what remains after complete saturation should totally refuse to mix. The acid, however, when too much diluted, precipitates the butter; but in proportion to its strength it dissolves a greater quantity. Arsenic.

1284 Arsenic mineralized by sulphur. Arsenic mineralized by sulphur is not dissolved by water, but is affected by the different acids, according to the particular circumstances of each. Nitrous acid and aqua-regia act most powerfully; the former soon destroys the red colour of the realgar, and converts it into yellow orpiment; its primary action being to calcine the arsenic, without affecting the yellowness of the sulphur. It makes no change on the colour of orpiment. Aqua-regia, by long digestion, takes up the arsenic, and leaves the sulphur at the bottom; and hence we may find out the proportions of the two ingredients. Some dexterity, however, is necessary in performing this operation with accuracy; for if, on the one hand, the menstruum be too weak, part of the arsenic will remain undissolved; and if, on the other, it be too strong, part of the sulphur will be decomposed; for strong nitrous acid is capable of decomposing sulphur by long digestion, having a greater attraction for phlogiston than the vitriolic acid itself. The colour of the residuum ought to be grey; for as long as any yellow particles remain, it is a sign that some of the arsenic also remains. If any iron be present in the compound, it is all dissolved, by reason of the superior attraction of the acid for it, before any of the arsenic is taken up, unless it shall have been calcined either by the access of air and heat employed in the operation, or by the too great power of the menstruum.

1285 Pure regulus of arsenic, how prepared. The pure regulus of arsenic may be obtained artificially from white arsenic, either by sublimation with oil, black flux, or other phlogistic materials; or by melting it with double its weight of soap and potashes; or lastly, by precipitation by means of some other metal, from orpiment or sandarack melted with sulphur and fixed alkali. By the first of these methods it is obtained in a crystalline form, octohedral, pyramidal, or even prismatic.

1286 Mispickel, a natural regulus of arsenic. Mr Bergman mentions a natural regulus of arsenic, named *mispickel*, which along with some sulphur contains a large quantity of iron united with the regulus into a metallic compound; but tho' the iron sometimes amounts to $\frac{1}{4}$ or even $\frac{2}{3}$ of the whole, it nevertheless remains untouched by the magnet. When ignited, it sends forth an arsenical smell, and soon becomes obedient to the magnet, even though the operation be performed on a tile without any additional phlogiston; it melts easily in an open fire, and in close vessels the greater part of the regulus sublimes, leaving the iron at the bottom.

1287 Great volatility of this semimetal. The pure regulus of arsenic is vastly more volatile than any other metal, and therefore cannot be melted. It begins to send forth a visible smoke in 180° of the Swedish thermometer, and is capable of inflammation; but in order to inflame it, it must be thrown into a vessel previously heated to a sufficient degree, otherwise it will be sublimed. The flame is of an obscure whitish blue, diffusing a white smoke and garlic smell. In close vessels it retains its metallic form, and may be sublimed of any figure we please.

1288 Effects of regulus of arsenic on other metals. Regulus of arsenic unites with many of the metals, but destroys the malleability of those with which it enters into fusion. It renders those more easy of fusion which are melted with difficulty by themselves; but tin, the most easily fusible of all the metals, becomes

comes more refractory by being united with arsenic. This metal acquires a permanent and shining whiteness by its union with regulus of arsenic, and is able to retain half its own weight of the arsenical metal. The other white metals become grey by fusion with this semimetal, platina only excepted. Gold fused in a close vessel with regulus of arsenic, scarcely takes up $\frac{1}{60}$ of its weight; silver $\frac{1}{4}$; lead $\frac{1}{6}$; copper $\frac{5}{6}$; and iron more than its own weight. The magnetic property of this last metal is destroyed by a large quantity of regulus, though the exact proportion which destroys it can scarcely be determined, as some of the iron is always taken up by the scoria; but according to Mr Bergman, less than an equal quantity is certainly sufficient. Bismuth retains $\frac{1}{15}$ of its weight; zinc $\frac{1}{5}$; regulus of antimony $\frac{1}{8}$; and manganese an equal quantity. Nickel and regulus of cobalt take up a large quantity; but how much cannot be determined, as it is next to impossible to procure any of those metals in a state of perfect purity. In a sufficient degree of heat, and by a triture of several hours, regulus of arsenic takes up about $\frac{1}{6}$ of its own weight of mercury, forming an amalgam of a grey colour.

1289 May be expelled by heat from all the metals with which it is united.

Regulus of arsenic, by reason of its volatility, may be expelled from all the metals with which it is united; but, in flying off, it generally carries along with it some of the metals with which it is united, gold and silver not excepted, if the degree of heat be great and very suddenly applied. Platina, however, perfectly resists the volatilization; and by reason of its refractory nature, even retains a portion of the arsenic.

1290 Effects of it upon alkaline salts and nitre.

This semimetal cannot be united by fusion with alkaline salts until the phlogiston is considerably diminished, and the regulus approaches to the nature of pure arsenical acid. By adding regulus therefore to nitre in fusion, a detonation ensues, the phlogiston of the former is totally destroyed, and the acid uniting with the alkali of the nitre forms a neutral arsenical salt, similar to that made with white arsenic and nitre. By distillation with dry acid of arsenic, the regulus sublimes before it can be acted upon by the acid; but when thrown into the acid in fusion, soon takes fire, and sends forth a white smoke: for the acid, being in this instance deprived of its phlogiston, separates that principle from the regulus, and unites with it in such quantity as to regenerate white arsenic; while on the other hand, the regulus, by this operation, is so far deprived of its phlogiston as to appear in the form of

1291 Decomposes corrosive sublimate.

a calx. By distillation with corrosive sublimate, a smoking butter, and small quantity of mercurius dulcis and running mercury, are procured; which happens in consequence of a double elective attraction; the regulus of arsenic yielding its phlogiston to the base of the corrosive sublimate, which being thus really calcined, reduces the former to perfect mercury, while the marine acid takes up the calx of arsenic. The regulus of arsenic readily unites with sulphur, and forms the same red and yellow compounds that have already been mentioned when speaking of white arsenic; it is soluble in hepar sulphuris, but may be precipitated by every other metal which can unite with the hepar.

1292 Converted into white arsenic by the vitriolic acid.

Regulus of arsenic is not affected by the vitriolic acid, unless when concentrated and assisted by heat. The inflammable part of the regulus which phlogisticates the acid flies off, so that the remainder assumes the nature of white arsenic, and exhibits the same properties with menstrua as any other metallic calx: the same holds good with nitrous acid, except that it attracts the phlogiston more vehemently. Marine acid has little or no effect except when boiling.

1293 Effects of it on metallic solution.

Regulus of arsenic precipitates certain metals dissolved in acids, such as gold and platina, dissolved in aqua-regia, as well as silver and mercury in vitriolic and nitrous acids. Silver generally appears in beautiful polished spiculæ, like the arbor Dianæ; but if the arsenic be suffered to stand long in the nitrous solution but little diluted, the silver spiculæ are again dissolved, the arsenic in the mean time being dephlogisticated. Solutions of bismuth and antimony are scarcely rendered turbid. Iron may be separated from regulus of arsenic by digestion with marine acid, or with aqua-regia; neither of which will touch the arsenic, as long as any iron remains; but in order to succeed in this operation, subtile pulverisation is necessary as well as a just quantity and strength of the menstruum. Heat must also be carefully avoided. The regulus is also dissolved by hepar sulphuris and by fat oils, the latter forming with it a black mass like plaster.

§ 12. Cobalt.

Regulus of cobalt, or more properly pure cobalt itself (what we have under the name of *cobalt* being only a calx of the regulus), is a semimetal of a reddish white colour, close-grained, so as to be easily reducible to powder, about 7.7 of specific gravity, and forming itself into masses of a needle-like texture, placed upon one another. It is seldom or never found native, but almost always calcined and united with arsenic, the arsenical acid, sulphur, iron, &c. The zaffre used in commerce is an impure and grey calx of cobalt. When mixed with three times its weight of pulverised flints, and exposed to a strong fire, it melts into glass of a dark blue colour, called *smalt*, used in tinging other glasses, and in painting. With three times its weight of black flux, a small quantity of tallow and marine salt, it affords the semimetal known by the improper name of *regulus of cobalt*; but the reduction is very difficult. For this purpose a large quantity of flux must be made use of, and the crucible kept a considerable time in a white-red heat, that the matter may become very fluid, and that the scoria may be completely fused into a blue glass, at which period the cobalt sinks in the form of a button to the bottom.

1294 Zaffre, a calx of cobalt.

1295 Smalt, how produced.

1296 Regulus of cobalt difficult to reduce.

1297 Properties of cobalt when exposed to heat.

Cobalt melts in a strong red heat, is very fixed in the fire, and it is uncertain whether it can be volatilized in close vessels. When suffered to cool slowly, it crystallizes in needle-shaped prisms, placed one upon the other, and united in bundles, having a considerable resemblance to masses of basaltes separated from each other: in order to succeed in this crystallization, however, the cobalt must be melted in a crucible till it begins to boil, and, when the surface of the metal becomes fixed on being withdrawn from the fire, the vessel is then to be inclined; that which still remains fluid runs out, and the portion adhering to the lumps formed by the cooling of the surface is found covered with crystals.

1298 Calcines spontaneously in the air.

This semimetal, exposed to the atmosphere, becomes covered with a dull pellicle, and undergoes a spontaneous calcination; but it may easily be calcined in

Cobalt.

in any quantity by expoſing it in powder in a ſhallow veſſel, under the muſſle of a cupelling furnace, and ſtirring it now and then to expoſe freſh ſurfaces to the air. After being kept red hot for ſome time, this powder loſes its ſplendor, increaſes in weight, and be-
1299 Its calx forms a beautiful blue glaſs.
comes black, the calx being convertible, by a moſt violent heat, into a blue glaſs. By fuſion it combines with vitrifiable earths, forming with them a beautiful blue glaſs extremely fixed in the fire; whence it is of the greateſt uſe in enamel-painting, porcelain-painting, &c. The action of terra ponderoſa, magneſia, and lime, on cobalt, is not known. Alkalies manifeſtly alter it; but in what reſpect is not known.

1300 Phenomena with vitriolic acid.

Cobalt diſſolves in concentrated vitriolic acid, when aſſiſted by a boiling heat; the acid evaporating almoſt entirely in the form of ſulphureous gas. The reſiduum is then to be waſhed; a portion of it diſſolves in the water, and communicates a greeniſh colour to it when warm, which changes to a roſe colour when cold. M. Beaumé affirms, that by ſufficiently evaporating the vitriolic ſolution of cobalt, two ſorts of cryſtals are obtained; one white, ſmall, and cubical; the other greeniſh, quadrangular, ſix lines in length, and four in breadth. Theſe laſt he only conſiders as the true vitriol of cobalt; the former being produced by certain foreign matters united to it. The cryſtals moſt commonly obtained have the form of ſmall needles, and may be decompoſed by fire, leaving a calx of cobalt not reducible by itſelf. They may likewiſe be decompoſed by all the alkalies, by terra ponderoſa, magneſia, and lime. According to Fourcroy, 100 grains of cobalt, diſſolved in the vitriolic acid, afford, by precipitation with pure mineral alkali, 140 grains of precipitate; by the ſame alkali aërated, 160 grains. Diluted vitriolic acid acts on zaffre, and diſſolves a part, with which it forms the ſalt already deſcribed.

1301 With nitrous acid.

Nitrous acid acts upon the ſemimetal with that violence which is its general characteriſtic; and the ſolution, when nearly ſaturated, appears either of a roſy brown or bright green colour. By ſtrong evaporation it yields a ſalt in ſmall needles joined together; which is very deliqueſcent, boils upon hot coals without detonation, and leaves a calx of a deep red colour. It is decompoſed by the ſame ſubſtances as the former, and by exceſs of alkali the precipitate diſappears.

1302 With marine acid.

Muriatic acid, aſſiſted by heat, diſſolves cobalt in part, but has no effect upon it in the cold. It acts more ſtrongly on zaffre, forming a ſolution of a reddiſh brown, which becomes green by being heated. By evaporation it yields a very deliqueſcent ſalt in ſmall needles, which becomes green when heated, and is ſoon after decompoſed. Aqua-regia diſſolves the metal more eaſily than the marine acid, but leſs ſo than the nitrous. The ſolution has been long known as a *ſympathetic Ink*.

1303 With the acid of borax.

Cobalt is not diſſolved directly by the acid of borax; but when a ſolution of this ſalt is mixed with a ſolution of cobalt in any of the mineral acids, a double decompoſition takes place; the alkaline baſis of the borax uniting with the acid which held the cobalt in ſolution; and the calx, combining with the ſedative ſalt, falls to the bottom in form of an inſoluble precipitate.

This ſemimetal is calcined by being heated to ignition with nitre. One part of cobalt, and two or three of dry nitre, well powdered and mixed, when thrown into a red-hot crucible; produce ſmall ſcintillations; a portion of the cobalt being converted into a calx of a red colour, more or leſs deep, and ſometimes of a green. 1304 With ſal ammoniac.
Sal ammoniac is not decompoſed, by reaſon of the little attraction there is between the metal and muriatic acid. M. Bucquet, who made the experiment with great care, could not obtain a particle of volatile alkali. 1305 With ſulphur.
Sulphur does not unite with it but very difficultly, and the combination is promoted by liver of ſulphur. Thus a kind of artificial one may be produced, the grain of which will be finer or cloſer, and its colour whiter or yellower, in proportion to the quantity of ſulphur in the mixture. M. Beaumé obſerves, that this compound cannot be decompoſed by acids, and that fire cannot deſtroy all the ſulphur.

§ 13. *Nickel.*

1306 Diſcovered by Mr Cronſtedt.

This was firſt diſcovered to be a ſemimetal of a peculiar kind by Cronſtedt, in the years 1751 and 1754, who procured it in the form of regulus from its ore, but without being able to reduce it to a ſufficient degree of purity; which indeed has not yet been done by any chemiſt. M. Bergman has laboured moſt in this way, though even he has not reduced it to the purity of other metallic ſubſtances. His experiments were made with ſome regulus made by M. Cronſtedt, and whoſe ſpecific gravity was to that of water exactly as 7.421 to 1. His attempts to purify it were made,

I. By Calcination and Scorification.

1307 Effects of calcination with a violent heat.

Nine ounces of powdered nickel were expoſed for ſix hours, in ſeveral portions, to a moſt violent heat, under the dome of an aſſay furnace. Thus the arſenic was firſt diſſipated with a fetid ſmell, after which the odour of ſulphur became perceptible; after this a white ſmoke aroſe without any ſmell of garlic, and which, according to our author, aroſe probably from the more dephlogiſticated part of the arſenic which now began to ſublime. The heaps (we ſuppoſe after the matter had been poured out of the diſhes, and yet retaining a great deal of heat), when hot, began to ſwell, and green vegetations aroſe from all the ſurface, reſembling ſome kinds of moſs, or the filiform lichen; a ferruginous aſh-coloured powder remained at bottom; and 0.13 of the whole were diſſipated during the operation. Half an ounce of this calx fuſed in a forge for four minutes, along with three times its weight of black flux, yielded a regulus reticulated on the ſurface; the areola of a hexangular figure, with very ſlender ſtriæ, diverging from a centre, full of little tubercles; it weighed 0.73 of half an ounce; was obedient to the magnet; and, when ſcorified with borax, left a blackiſh glaſs.

By a ſecond roaſting the regulus again emitted a garlic ſmell; afterwards a viſible fume without any ſmell, with vegetations as before. The roaſted powder, reduced with black flux as before, ſtill emitted a ſmell of arſenic; but on repeating the fuſion with the calx and borax, nothing but ſome obſcure ſigns of cobalt appeared. A third calcination ſeemed to have much diſſipated the arſenic, as it now emitted but little of that kind of ſmell; the vegetations were alſo gone; and the matter had rather a ferruginous than a green

Nickel. green colour. Nearly the same phenomenon appeared after reduction in a fourth operation.

On performing the reduction with lime and borax, the regulus, when first melted, lost much of its ferruginous matter, which adhered to the black scoriæ; it soon acquired an hyacinthine colour, without any remarkable mixture of cobalt, was little obedient to the magnet, and its specific gravity was somewhat diminished, being now only 7.0828.

By a fifth calcination, gradually adding a quantity of powdered charcoal while the matter continued red hot, a prodigious quantity of arsenic, imperceptible before, flew off in the form of vapour; the arsenical acid being thus furnished with as much phlogiston as was necessary to make it rise in fume. The regulus was treated in this manner until no more arsenical smoke could be perceived; it was now of a lamellated and tenacious texture when reduced, but still diffused the arsenical odour on being removed from the fire. The roasting was therefore repeated a sixth time, and continued for ten hours; the addition of powdered charcoal continued to dissipate the arsenic in invisible vapours which yet were perceptible by the smell; the colour of the metallic calx was obscurely ferruginous, with a mixture of green scarcely visible. On reducing the regulus with equal parts of white flux, lime and borax, a semiductile regulus was obtained, highly magnetic, and soluble in nitrous acid, to which it communicates a deep green colour; a blackish mass remained, which afterwards become white, and when laid on a burning coal, flies off without any remarkable arsenical smell. The regulus being then six times fused with lime and borax, the scoriæ resembled the hyacinth in colour, and the metallic part was surrounded with a green calx. The regulus, as before, was magnetic and semi-malleable. Lastly, it was exposed for 14 hours to a very strong heat; when the powdered charcoal was added by degrees without any dissipation of arsenic or loss of weight; the colour of the roasted powder was ferruginous, with a very slight tinge of green. On reduction, a very small globe, still magnetic, was found among the scoriæ.

II. By Sulphur.

1308 Effects of sulphur and borax.

Eight hundred parts of Cronstedt's regulus of nickel, fused with sulphur and a small quantity of borax, yielded a mineralized mass of a reddish yellow, whose weight amounted to 1700. On exposing one half of this to the fire, it began to grow black; on which the heat was augmented until vegetations appeared; the remaining calx weighed 652. Melting this part with borax, and the other which had not been exposed to the fire, a sulphurated regulus of a whitish yellow colour was obtained, weighing 1102. The same regulus, calcined for four hours, was first covered with vegetations, and then, on the addition of powdered charcoal, diffused an arsenical odour; the metallic calx was green, and weighed 1038. A whitish yellow regulus was obtained semiductile, highly magnetic, and extremely refractory, weighing 594. By fusion with sulphur a second time, it weighed 816; one half of which roasted to greenness, united by means of fire to the other half still sulphurated, weighed 509, and was almost deprived of its magnetic quality. A calcination of four hours, during which phlogiston was added, dissipated a considerable quantity of arsenic; the powder put on an ash-colour, somewhat greenish, was in weight 569; and by reduction yielded a regulus whose surface was red, and which, on breaking, appeared of a white ash-colour, very friable, and weighing 432; the specific gravity 7.173.

On mineralizing the regulus a third time with sulphur, adding charcoal as long as any vestige of arsenic remained, which required a violent calcination of 12 hours, the remaining powder was of an ash-green colour, and weighed 364; but the regulus obtained by means of a reduction effected by the most violent heat in a forge for three quarters of an hour, was so refractory that it only adhered imperfectly to the scoria, which were of a distinct hyacinthine colour; nor could it be reduced to a globule by means of borax, though urged by the same vehemence of fire. The absolute gravity of this regulus was 180; its specific gravity 8.666. Its magnetic virtue was very remarkable; for it not only adhered strongly to the magnet, but to any other piece of iron; and the small pieces of it attracted one another. It had a considerable ductility, was of a whitish colour, mixed with a kind of glittering red; dissolved in volatile alkali, yielding a blue solution, and a green one in nitrous acid.

An hundred parts of the same regulus, beaten out into thin plates, were covered by a calcination of four hours, with a crust apparently martial, having under it a green powder, and within it a nucleus consisting of reguline particles still unchanged; the weight being increased by 5. The friable matter, reduced to powder, put on a brownish-green colour; and after a calcination of four hours more, concreted at the bottom in form of a friable black crust, strongly magnetic, and weighing 100: No vestiges of arsenic were discovered by a succeeding operation, in which charcoal was added; nor was the magnetic powder destroyed, but the weight was increased to 105, and the colour somewhat changed. By fusion for an hour with lime and borax, this powder yielded a regulus of an angular structure, red, semiductile, and altogether magnetic; the specific gravity being 8.875. The same globule dissolved in aqua-regia, was precipitated by green vitriol, as if it had been loaded with gold; but the precipitate was readily soluble in nitrous acid. Most of the reguli showed no signs of precipitation with green vitriol.

III. With Hepar Sulphuris.

1309 Effect of hepar sulphuris.

Fifty-eight parts of regulus of nickel, which had been sulphurated before, being fused with 1800 parts of saline hepar sulphuris, then dissolved in warm water, filtered through paper, and precipitated by an acid, yielded a powder, which, by calcination till the sulphur was driven off, appeared of an ash-colour, and weighed 35. The insoluble residuum, deprived of its sulphur by means of fire, was likewise of an ash-colour, and weighed 334. On reducing this regulus by means of the black flux, a friable regulus was obtained, which had a very weak magnetic property; but, on fusion with borax, this quality was augmented. On mixing and melting together equal parts of calx of nickel, gypsum, colophony, and white flux, a powdery, squamous, and reguline mass was produced; which, by fusion with borax, afforded a regulus possessing the properties

Nickel. perties of nickel, but not entirely destitute of cobalt, which obeyed the magnet, and did not part with its iron even after two solutions in the nitrous acid, and various reductions by fusion with borax; the sulphur was also retained with great obstinacy.

On dissolving regulus of nickel by fusion, in hepar sulphuris made with fixed alkali, adding a quantity of nitre sufficient only to destroy a small part of the hepar, the regulus which had been suspended by it was separated, and fell to the bottom. On examining this regulus, it appeared more pure, and generally deprived of cobalt, but still containing iron. In like manner nickel is always very distinctly precipitated by regulus of cobalt, as this latter is attracted more powerfully by the hepar sulphuris. When dissolved by fusion with hepar sulphuris, this semimetal may be precipitated by adding iron, copper, tin, or lead, and even by cobalt: the regulus obtained is indeed scarcely ever attracted by the magnet; but we are not from thence to conclude that it does not contain any iron; for when the heterogenous matters, which impede its action, are properly removed, it then acknowledges the power of the magnet very plainly.

IV. By Nitre.

1310 Of nitre. One part of Cronstedt's regulus was added to twelve of nitre ignited in a crucible, and kept red-hot for about an hour. Some weak flashes appeared first; then a large quantity of arsenic was emitted; and, lastly, the sides were covered with a blue crust occasioned by the cobalt, a green matter remaining at bottom. This, fused again for an hour, with twelve parts of nitre, tinged the internal sides of the vessel of a green colour; and, lastly, a brownish green mass, much less in quantity than in the former operation, was left at the bottom. This green matter, treated in the same way for two hours a third time, left a grey scoria at the bottom, which yielded no regulus with black flux.

Another portion of the same regulus, treated in the same way with nitre, was dissolved, and became green; yet on being freed by ablution from the alkaline salt, it yielded no regulus with black flux, but only scoria of an hyacinthine colour mixed with blue, tinging nitrous acid of a green colour, concreting into a jelly, and on evaporation leaving a greenish calx behind.

Another portion of Cronstedt's regulus was kept some hours in the crucible with 16 parts of nitre; by which means all the arsenic was first separated; then the phlogisticated nitrous acid; and, lastly, the sides of the vessel were penetrated by a kind of green efflorescences. The mass, after being washed with water, was of a dilute green colour, and tinged borax of a greenish brown. A green powder was still yielded, after treating this in the same manner with 12 parts of nitre; and on reducing it with one-half black flux, one-eighth borax, and as much lime, a yellowish white regulus, both magnetic and malleable, was obtained, possessing all the properties of nickel. Its specific gravity was 9.000; the phlogistic ingredient was used in small quantity, that the iron might, if possible, enter the scoria.

1311 Nitre capable of separating all the cobalt from nickel. It having appeared from this and some other experiments, that nitre was capable of discovering the smallest quantity of cobalt contained in nickel the products of the former operations were now subjected to its action. The regulus produced by repeated scorification thus became a little blue; that dissolved in volatile alkali (to be afterwards particularly mentioned) discovered a considerable quantity of cobalt, nor was there any one which did not thus discover more or less of that ingredient by this trial.

V. By Sal Ammoniac.

1312 Effect of sal ammoniac. A calx of nickel, so much freed from cobalt that it did not tinge borax in the least, mixed with twice its weight of sal ammoniac, yielded by sublimation with a strong red heat, two kinds of flowers; one, which rose higher than the other, was of an ash colour; the other white. The botton of the glass was stained of a deep hyacinthine colour; the residuum was divided into two strata; the upper one yellow, scaly, and shining like mosaic gold. With borax it afforded an hyacinthine glass, but not regulus; and in a few days liquefied in the air, acquiring a green colour and the consistence of butter. The residuum showed the same properties with calx of nickel; and the green solution showed no vestiges of iron with galls, but became blue with volatile alkali; which was also the case with the flowers. The lower stratum contained a calx, blackish on the upper part, but of a ferruginous brown in the under, with a friable and scarcely magnetic regulus, of a reddish white. The blackish calx yielded an hyacinthine glass with borax. Part of this stratum sublimed with twice its quantity of sal ammoniac; and with the same degree of heat as before, yielded flowers of a very fine white, with a residuum of ferruginous brown, greenish on the upper part towards the sides of the vessel, the bottom being stained of an hyacinthine colour as before. Twenty parts of sal ammoniac being added to a part of the inferior stratum reduced, the whole was sublimed in a retort; a blackish powder remained, which became green by calcination, and of an hyacinthine colour by scorification, as did also the bottom of the containing vessel. The sublimation being twice repeated, using a double quantity of sal ammoniac each time, the calx became at length very green, dissolving with the same colour in the nitrous acid, and yielding by reduction a white, brittle, and very little magnetic regulus. In all these sublimations, it was observed, that the volatile alkali rose first; then sal ammoniac; and, lastly, a part of the marine acid was forced over by the violence of the heat.

VI. With Nitrous acid.

1313 Effects of antimony. Having obtained a salt by crystallization from nickel dissolved in nitrous acid, part of this was calcined with charcoal dust in a proper vessel, and during the operation a large quantity of arsenic was dissipated; a grey, semiductile, and magnetic regulus being obtained after reduction. A brittle regulus was obtained after a second solution, precipitation, and reduction; but by a third operation it became again semiductile and magnetic. By repeating this process a fourth and fifth time, the quantity became so much diminished that it could no longer be tried. In all these solutions a blackish residuum appeared; which, when suffered to remain in the acid, grew white by degrees; but when edulcorated and laid on a burning coal, exhaled a sulphureous smoke, and left a black powder soluble in the nitrous acid.

VII. By

Nickel.

VII. By volatile Alkali.

1314 Volatile alkali.

Four hundred and eighty-seven parts of a calx of nickel, produced by diffolving Cronftedt's regulus in nitrous acid, and precipitating the folution by a fixed alkali, being immerfed for 24 hours in a quantity of volatile alkali, yielded a refiduum of fifty, having a blackifh green colour. The folution, which was blue, by filtration and infpiffation yielded a powder of a light blue colour, weighing 282; which, reduced with black flux, produced a white, femiductile, and highly magnetic regulus, weighing 35, whofe fpecific gravity was 7.000. The fcoriæ were of a light red: but when mixed with borax, put on an hyacinthine colour, and yielded a regulus weighing 30. The two reguli united together proved very refractory; fo that the mafs could not be melted by the blow-pipe, even with the addition of borax. It fent forth neither an arfenical nor fulphureous fmell on the addition of charcoal-duft; but, on a fucceeding reduction, yielded hyacinthine fcoriæ; and the remaining flocculi, diffolved in nitrous acid, affording a very green folution, which, on the addition of volatile alkali, yielded a powder of the fame colour.

From 50 parts of the blackifh green refiduum, 13 of a clear white, brittle, fquamous, and little magnetic regulus, were obtained, the fpecific gravity of which was 9.333. At the bottom of the veffel was found a fcoria of an obfcurely blue colour, with the upper part hyacinthine. It was eafily fufed; and tinged borax, firft blue, then of a hyacinth colour, upon which it became more ftrongly magnetic. By the affiftance of heat it diffolved in nitrous acid, forming a folution of a beautiful blue colour. A black powder at firft floated in the liquor, but became white, and fell to the bottom. After edulcoration it was for the moft part diffipated, with a fulphureous fmell, on being expofed to the fire; a little brown-coloured mafs, foluble in volatile alkali, remaining at bottom. This folution was precipitated by phlogifticated alkali, and a powder thrown down of the colour of calx of nickel, which foon grew blue with volatile alkali.

1315 Nickel cannot be obtained in a ftate of purity.

From all thefe experiments it appears, that nickel cannot be obtained in a ftate of purity by any means hitherto known. From every other fubftance, indeed, it may be feparated, except iron; but this refifts all the operations hitherto defcribed, and cannot be diminifhed beyond certain limits. The magnet not only readily difcovers its prefence, but fome portions of the regulus itfelf becomes magnetic; but the tenacity and difficulty of fufion, which increafe the more in proportion to the number of operations, plainly fhow that there is no hope of feparating the whole quantity, unlefs we fuppofe the regulus of nickel itfelf to be attracted by the magnet; and there is certainly a poffibility that one other fubftance befides iron may be attracted by the magnet. The great difficulty, or rather impoffibility, of obtaining it in a ftate of purity, naturally raifes a fufpicion of its not being a diftinct

1316 Bergman's opinion of the compofition of nickel.

femimetal, but a mixture of others blended together; and on this fubject our author agrees in opinion with thofe who fuppofe it to be a compound of other metals. Indeed, Mr Bergman is of opinion, that "nickel, cobalt, and manganefe, are perhaps no other than modifications of iron." And in order to afcertain this, he made the following experiments.

1317 Experiments to compofe nickel artificially.

1. Equal parts of copper, of the gravity of 9.3243, and iron of 8.3678, united by fufion with black flux, yielded a red mafs, whofe fpecific gravity was 8.5441; and which tinged nitrous acid firft blue, then green, afterwards yellow, and at laft of an opaque brown. 2. Two parts of copper and one of iron had a fpecific gravity of 8.4634; the mixture yielding firft a blue, and then a green folution. 3. Equal parts of copper and iron, of the fpecific gravities already mentioned, with another part of cobalt whofe gravity was 8.1500, yielded a metal of the gravity of 8.0300, imparting a brown colour to the folution. 4. Two parts of arfenic of 4.000, added to one of copper and another of iron, gave a brittle metal of 8.0468, which formed a blue folution. 5. One part of copper, one of iron, two of cobalt, and two of white arfenic, gave a brittle regulus of 8.4186; the folution of which was brownifh, and feparated in part fpontaneoufly. 6. One part of copper, one of iron, four of cobalt, and two of white arfenic, formed a mafs of 8.5714. The folution was fomewhat more red than the former; and a fimilar effect took place on repeating the experiment, only that the fpecific gravity of the metal was now 8.2941. 8. One part of iron and four of white arfenic formed a metal which diffolved with a yellow colour; and, on the addition of Pruffian alkali, immediately let fall a blue fediment. 9. One part of copper, eight of iron, fixteen of white arfenic, and four of fulphur, united by fire, on the addition of black flux, yielded a mafs which, though frequently calcined and reduced, produced nothing but brown or ferruginous calces. It acquired a greennefs with nitrous acid; but on the addition of phlogifticated alkali depofited a Pruffian blue. 10. One part of iron was diffolved in fix of the nitrous acid, and likewife feparated by one part of copper and one of the calcined ore of cobalt, in the fame quantity of the fame acid. The whole of the folution of iron was then mixed with five parts of the folution of copper, whence a green and faturated nickel colour was produced; which, however, on the addition of three parts of the folution of cobalt, became evidently obfcured. The alkaline lixivium dropped into this threw down at firft a ferruginous brown fediment, the folution ftill remaining green: afterwards all the blue was precipitated; by which at firft all colour was deftroyed, but afterwards a red appeared, occafioned by the cobalt diffolved in the alkaline falt. The fediment, when reduced, yielded a regulus fimilar to copper, and at the fame time ductile, which tinged both glafs and nitrous acid of a blue colour. If a faturated folution of nickel be mixed with half its quantity of folution of cobalt, the green colour is much obfcured; but four parts of the former, on the addition of three of the latter, put off all appearances of nickel. See the article NICKEL.

§ 14. *Of Platina.*

1318 The heavieft of all metals.

THE properties of this metal have not as yet been thoroughly inveftigated by chemifts, and there is therefore fome difagreement concerning them. Formerly it was fuppofed to be inferior in fpecific gravity to gold;

Platina. gold; but now is generally allowed to be ſuperior in that reſpect by little leſs than a fourth part; being to water in the proportion of 23 to 1 when perfectly freed from all heterogeneous matters. Mr Bergman ſays that its colour is that of the pureſt ſilver. The very ſmall globules of it are extremely malleable; but when many of theſe are collected together, they can ſcarcely be ſo perfectly fuſed as to preſerve the ſame degree of malleability. They are not affected by the magnet in the leaſt, nor can they be diſſolved in any ſimple menſtruum excepting dephlogiſticated marine acid. As it is commonly met with, however, platina has the form of ſmall grains, its plates of a bluiſh black, whoſe colour is intermediate betwixt thoſe of ſilver and iron. Theſe grains are mixed with many foreign ſubſtances, as particles of gold, mercury, and blackiſh ferruginous, ſandy grains, which by the magnifier appear ſcorified. The grains themſelves, when examined by a magnifying glaſs, appear ſometimes regular, ſometimes round and flat, like a kind of button. When beat on the anvil, moſt of them are flattened and appear ductile; ſome break in pieces, and on being narrowly examined appear to be hollow, and particles of iron and a white powder have been found within them: and to theſe we muſt attribute the attraction of platina by the magnet; ſince, as we have already obſerved, pure platina is not attracted by it.

1319 Inſoluble except by dephlogiſticated marine acid.

1320 Found in ſmall grains intermixed with foreign ſubſtances.

1321 Mr Bergman's experiments on this metal.

Mr Bergman, who carefully examined this metal, diſſolved it firſt in aqua-regia compoſed of the nitrous and marine acid. The ſolution at firſt exhibits a yellow colour, but on approaching to ſaturation became red, and the redneſs increaſes as the liquor becomes more loaded with metal. Cryſtals are produced by evaporation of a deep red colour, generally in ſmall angular and irregular grains, whoſe true ſhape cannot be diſcovered. Their appearance is ſometimes opaque and ſometimes pellucid. After theſe are once formed, they are extremely difficult of ſolution, requiring much more water than even gypſum itſelf for this purpoſe.—The ſolution is not precipitated by vegetable fixed alkali, nor does the latter affect the cryſtals, except very faintly by digeſtion with them in a cauſtic ſtate. Aerated mineral alkali takes them up and grows yellow, but without depoſiting any thing, though it decompoſes them at laſt by evaporating to dryneſs.

1322 Cryſtals of platina may be decompoſed by mineral but not vegetable fixed alkali.

On the addition of a ſmall quantity of vegetable fixed alkali, either mild or cauſtic, ſmall red cryſtals ſoluble in water, and ſometimes of an octohedral figure, are depoſited. They are decompoſed with difficulty by the mineral alkali, but not at all by the vegetable. If a larger quantity of ſalt is added at firſt, an inſoluble ſpongy matter of a yellow colour is precipitated. Cryſtalline particles of the ſame kind are thrown down by an alkali ſaturated either with the vitriolic, nitrous, marine, or acetous acids, though all the platina cannot thus be ſeparated from the menſtruum.

1323 Solution in aqua-regia made with nitrous acid and that of ſea ſalt.

Aqua-regia, compoſed of nitrous acid and common ſalt, diſſolved the metal with equal facility as the former; only the ſolution was more dilute, and a yellow powder floated on the ſurface, a larger quantity being found at the bottom. On adding vegetable fixed alkali to the clear ſolution, a copious yellow powder, ſoluble in a large quantity of water, was depoſited. A powder, of a ſimilar kind, was precipitated, tho' more ſlowly, and more of a cryſtalline nature; but mineral alkali, though uſed in much larger quantity, did not make any alteration. The collected powder was yellow, and agreed in property with that ſeparated ſpontaneouſly in a former experiment.

1324 In a liquor compoſed of nitre and ſpirit of ſalt.

On repeating the experiment with nitre and depurated ſpirit of ſalt, inſtead of nitrous acid and ſea-ſalt, the platina was diſſolved into gold-coloured liquor, a greeniſh coloured granulated matter falling to the bottom, and the finer part of the ſame riſing to the top. After ſaturating the ſuperfluous acid, a metallic calx, inſoluble in water, was thrown down by the vegetable alkali. The green powder is ſoluble in water, and is of the ſame nature with the precipitate thrown down by the vegetable alkali.

1325 Cryſtalline powder precipitated by vegetable alkali from ſolution of the calx in marine acid;

1326 But not from the ſolution in nitrous acid.

Platina precipitated from aqua-regia by a ſufficient quantity of mineral alkali, the precipitate waſhed and diſſolved in marine acid, on the addition of vegetable alkali immediately lets fall a cryſtalline powder, as it does alſo with nitre and other ſalts, having the vegetable alkali for their baſis. The caſe is the ſame with calx of platina, diſſolved in vitriolic acid. Nitrous acid alſo diſſolves the calx of platina, but does not yield any diſtinct ſaline precipitate without the aſſiſtance of marine acid.—The above phenomena are likewiſe produced by the precipitate thrown down by the vegetable alkali after the ſaline powder has been depoſited.

1327 This precipitate a kind of triple ſalt.

From theſe experiments our author concludes, 1. That the precipitate which is firſt thrown down, on the addition of vegetable alkali to ſolutions of platina, is a ſaline ſubſtance, and different from the calx of the metal. 2. That this ſaline precipitate is compoſed of calcined platina, marine acid, and vegetable alkali. 3. By means of vitriolic acid, a precipitate analogous to this may be obtained, compoſed of calcined platina, vegetable alkali, and vitriolic acid. 4. The whole ſolution of platina cannot be precipitated by vegetable alkali in form of a triple ſalt; but after paſſing a certain limit, a metallic calx in the uſual way is produced.

1328 Whether mineral alkali can ſeparate platina from its ſolvent.

As it has been denied by Margraaf and Lewis that mineral alkali is capable of ſeparating platina from its acid, our author was induced to attend particularly to this circumſtance. Having therefore tried the common ſolution with mineral alkali, he found that each drop excited a violent efferveſcence, and at laſt that a yellow ſpongy matter, affording a genuine calx of platina, was precipitated: this was more ſpeedily effected by uſing the dry mineral alkali, which had fallen to powder of itſelf. To determine, however, the difference betwixt the two alkalies in a more accurate manner, he divided a very acid ſolution of platina into two equal parts. To one of theſe, he added ſmall portions of the vegetable, and to the other an equal weight of pieces of mineral alkali, waiting five minutes after every addition, till the efferveſcence ſhould fully ceaſe. After the firſt addition, ſmall cryſtals appeared; in the former partly on the ſurface, and partly in the bottom; but in the latter no precipitate could be obſerved until 56 times the quantity of vegetable alkali had been added. The difference, however, was even greater than what appears from this experiment; for the vegetable alkali was cryſtallized, and therefore charged with the water neceſſary to its cryſtalline form;

1329 Fifty-ſix times as much mineral alkali required to precipitate platina as of vegetable alkali.

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form; whereas the mineral alkali was ſpontaneouſly calcined: and though, in equal quantities of theſe two alkalies, the purely alkaline parts are as 3 to 2, yet three parts of vegetable alkali ſaturated only 1.71 of this aqua-regia, while two of the mineral alkali took up about 2.6.

1330
Effects of the volatile alkali.

The volatile alkali firſt throws down this metal in a ſaline form; the grains ſometimes diſtinctly octohedral. Their colour is red when that of the ſolution is ſo, but yellow when the ſolution is more dilute. After ſaturating the ſuperabundant acid, the ſame alkali precipitates the platina truly calcined. This precipitate is diſſolved in water, though with difficulty, and may be reduced to more regular cryſtals by evaporation. Theſe are diſſolved by the mineral alkali; but hardly any ſigns of decompoſition are to be obſerved, unleſs the yellow ſolution, evaporated to dryneſs, be again diſſolved in water; for then the metallic calx reſts at the bottom, and the ſolution is deprived of its yellow colour. The vegetable alkali has ſcarce any effect in this way; for, after repeated exſiccation, the ſolution remains clear and yellow: but here probably the fixed alkali takes the place of the volatile; for in larger quantities, and eſpecially when the cauſtic vegetable alkali is made uſe of, the mixture ſmells of volatile alkali.

1331
Platina partly precipitated by neutral ſalts.

The volatile alkali, ſaturated with any acid, precipitates the platina in the ſame manner as the vegetable alkali in combination with acids: but theſe neutral ſalts precipitate only a determined quantity of platina; for after their effect has ceaſed, the liquor lets fall a pure calx of platina on the addition of vegetable or volatile alkali.

1332
Triple ſalts formed by this metal.

The calx of platina precipitated by mineral alkali, and then diſſolved in any ſimple acid, ſhows nearly the ſame phenomena with volatile alkali as with the vegetable alkali. "Whence (ſays Mr Bergman) we may conclude, that platina diſſolved in acids forms at firſt, both with the volatile and fixed vegetable alkali, a triple ſalt, difficult of ſolution, and which therefore almoſt always falls to the bottom unleſs the quantity of water be very large." Calcareous earth, whether aerated or cauſtic, produces the ſame phenomena as the mineral alkali, without any cryſtalline appearance.

1333
Platina the moſt infuſible ſubſtance in the world.

Platina has been remarkable ever ſince its firſt diſcovery for being the moſt infuſible ſubſtance in the world. Meſſrs Macquer and Beaumé kept it in the moſt violent heat of a glaſs-houſe furnace for ſeveral days without perceiving any other alteration than that its grains adhered ſlightly to each other; but the adheſion was ſo ſlight that they ſeparated even by touching. In theſe experiments the colour of the platina became brilliant by a white heat, but acquired a dull grey colour after it had been heated for a long time. They obſerved alſo, that its weight was conſtantly increaſed; which undoubtedly aroſe from the calcination of the iron it contained. Dr. Lewis, after various attempts to fuſe platina, found himſelf unable to ſucceed even in a fire which vitrified bits of glaſs-houſe

1334
Firſt melted by a burning mirror.

pots and Heſſian crucibles. Meſſrs Macquer and Beaumé firſt melted this refractory metal with a large burning-glaſs, 22 inches diameter and 28 inches focus. The power of this ſpeculum was almoſt incredible, and far exceeded what is related of the lens of Tſchirnhauſen or the mirror of Villette. Its general effects are related under the articl *Burning-Glaſs*. And as platina reſiſted this intenſe heat more than ſix times as long as the moſt unfuſible ſubſtances formerly known, it appears to require a fire as many times ſtronger to melt it. It has been found, however, capable not only of fuſion but of vitrification by the electric fire; and that it may alſo be melted by fire excited by dephlogiſticated air: but M. de Liſle was the firſt who was able to melt it with the heat of a common forge when expoſed to the blaſt of a double bellows in a double crucible. Thus its real ſpecific gravity began firſt to be known. It muſt be obſerved, however, that this fuſion was not performed on common platina, but on ſuch as had been diſſolved in aqua-regia and precipitated by means of ſal ammoniac. M. Morveau repeated the experiment, and from 72 grains of platina obtained a regulus weighing 50½; which ſeemed to have undergone a very imperfect fuſion; for it did not adhere to the crucible or take its form, but ſeemed to be merely platina revived. Its ſpecific gravity was alſo found to be no more than 10.045; but it was nearly as malleable as ſilver; and when it had been ſufficiently hammered, its ſpecific gravity was augmented to no leſs than 20.170, which is more than that of gold itſelf. M. Morveau found that he could melt the precipitate with different fluxes, ſuch as a mixture of white glaſs, borax, and charcoal, and a mixture of white glaſs and neutral arſenical ſalt: and that the regulus thus obtained was more completely fuſed, but was not malleable, and obeyed the magnet; but the regulus obtained without addition did not ſhow this mark of containing iron. He alſo found, that by means of the abovementioned flux of white glaſs, borax, and charcoal, he could melt crude platina. Since that time the fuſion of platina has been accompliſhed by various chemiſts, and with different fluxes; and in proportion to the degree of purity to which the metal has been reduced, its ſpecific gravity has alſo increaſed; ſo that it is now ſettled at 23, that of fine gold being 19.

Platina.

1335
May be vitrified by electric fire.

1336
Its precipitate fuſible in a common forge.

1337
This precipitate, or even crude platina, fuſible by the aſſiſtance of fluxes.

1338
Alloyed by Dr Lewis with other metals.

Though Dr Lewis could not accompliſh the fuſion of platina by the methods he attempted, he was nevertheleſs able to alloy it with other metals. Equal parts of gold and platina may be melted together by a violent fire, and the mixed metal formed into an ingot by pouring it into a mould. It is whitiſh, hard, and may be broken by a violent blow; but when carefully annealed, is capable of conſiderable extenſion under the hammer. Four parts of gold with one of platina form a compound much more fuſible than the former, and likewiſe more malleable; ſo that it may be extended into very thin plates without being broken or even ſplit at the edges. Dr Lewis remarks alſo, that though in this caſe it be alloyed with ſuch a quantity of white metal, it nevertheleſs appears no paler than guineas uſually are, which contain only one-twelfth of ſilver.

1339
With gold.

1340
With ſilver.

Equal parts of ſilver and platina melted together with a violent fire, form a much harder and darker-coloured maſs than ſilver, which has alſo a large grain, though it preſerves ſome ductility. Seven parts of ſilver with one of platina form a compound much more reſembling ſilver than the other; but ſtill coarſer-grained and leſs white. From the experiments made on ſilver, however, it appears that no perfect union is

formed

Platina.

formed betwixt the two; for after the mixture has been kept in fufion for a confiderable time, moft of the platina feparates and falls to the bottom. Lewis obferved that filver melted with platina was thrown up with an explofion againft the fides of the crucible.

Silver did not appear to be in any degree meliorated by its union with this metal, excepting by the fuperior

1341 Copper confiderably improved by union with platina.

hardnefs communicated to it; but copper feemed to be confiderably improved. A large proportion of platina, indeed, as two thirds or equal parts, produced an hard, brittle, and coarfe-grained compound; but when a fmaller quantity of platina is added, as from $\frac{1}{6}$ to $\frac{1}{12}$, or even lefs, a golden-coloured copper is produced, very malleable, harder, fufceptible of a finer polifh, fmoother-grained, and much lefs fubject to calcination and ruft than pure copper.

1342 Unites moft readily with zinc;

Of all metallic matters, however, zinc moft readily unites with platina, and is moft effectually diffolved by fufion. When the proportion of platina is confiderable, the metal is of a bluifh colour, the grain clofer, without tarnifhing or changing colour in the air, and they have not even the malleability of the femi-metal.

1343 And with the compound metals.

Platina unites readily with the compound metals, brafs formed of copper and zinc, and bronze made of copper and tin. In the latter it was remarkable, that the compound metal took up more platina than both its ingredients feparately can do. This compound was hard and capable of receiving a fine polifh, but is fubject to tarnifh.

1344 The compound of brafs and platina a proper material for fpeculums.

Equal parts of brafs and platina formed a compound very hard, brittle, capable of receiving a fine polifh, and not fubject to tarnifh. It is poffible therefore that it might be ufed to advantage as a material for fpeculums; all materials for which, hitherto difcovered, have the great inconvenience of tarnifhing in the air, and that very quickly.

1345 Can fcarce be united with mercury.

Platina amalgamates with mercury, but with much greater difficulty than gold, which will alfo feparate the quickfilver after it has been united with the platina. The amalgamation of platina does not fucceed but by very long trituration of the metals with water, as for inftance a week; but if the trituration be per-

1346 Mercury leaves platina to unite with gold.

formed with a mixed metal compofed of gold and platina, the mercury feizes the gold, and leaves the platina untouched. Dr Lewis propofes this as a method of feparating gold from platina; and it is that ufed in Peru, where gold and platina are fometimes naturally mixed in the ore; but we do not know whether this feparation be quite complete.

1347 May be united with forged and caft iron;

Mr Morveau fucceeded in uniting iron with platina, though Dr Lewis could not accomplifh this. The latter fucceeded, however, in uniting it with caft iron. The compound was much harder and lefs fubject to ruft than pure iron. It was alfo fufceptible of a much finer polifh.

1348 And with tin, lead, or bifmuth.

Platina may be alloyed with tin, lead, or bifmuth, but without any advantage. To lead and tin it gives the property of affuming blue, violet, or purple colours, by being expofed to the atmofphere.

Dr Lewis could not fucceed in uniting platina with arfenic; but M. Scheffer affirms, that if only one twentieth of arfenic be added to platina when red hot in a crucible, the two fubftances will be perfectly fufed and united into a brittle grey mafs. This experiment did not fucceed with Mr Margraaf; for he, having expofed to a violent fire during an hour a mixture of an ounce of platina with a fufible glafs, compofed of eight ounces of minium, two ounces of flints, and one ounce of white arfenic, obtained a regulus of platina well united and fufed, weighing an ounce and 32 grains; the furface of which was fmooth, white, and fhining, and the internal parts grey; but which neverthelefs appeared fufficiently white when filed. The experiment fucceeded imperfectly alfo in the hands of Dr Lewis; but M. Fourcroy informs us, that "it has fince been repeated, and that platina is in fact very fufible with arfenic, but that it remains brittle. In proportion as the arfenic is driven off by the continuance of the heat, the metal becomes more ductile; and by this procefs it is that M. Achard and M. de Morveau fucceeded in making crucibles of platina by melting it a fecond time in moulds." (A)

1349 May be melted by means of arfenic.

1350 Fourcroy denies that platina can be united with mercury.

M. Fourcroy feems to deny that platina can be united with mercury, contrary to what is mentioned above. "Platina (fays he) does not unite with mercury, though triturated for feveral hours with that metallic fluid. It is likewife known, that platina refifts the mercury ufed in America to feparate the gold. Many intermediums, fuch as water, ufed by Lewis and Beaumé, and aqua-regia by Scheffer, have not been found to facilitate the union of thefe two metals. In this refpect platina feems to refemble iron, to whofe colour and hardnefs it likewife in fome meafure approaches." This laft fentence, however, feems very

1351 Inconfiftent in his account of its hardnefs.

little to agree with what he himfelf had before told us of M. Macquer's experiment of melting platina. "The melted portions (fays he) were of a white brilliant colour, in the form of a button; they could be *cut to pieces* with a knife." This furely was a very fmall approach to the hardnefs of iron; and gives us an idea rather of the confiftence of tin or lead. "One of thefe maffes was flattened on the anvil, and converted into a thin plate without cracking or breaking, but it became hard under the hammer." In another experiment indeed the button of platina was brittle, and fufficiently hard to make deep traces in gold, copper, and even iron; but this was obtained from precipitated platina urged for 35 minutes by a ftrong blaft furnace. In an experiment of this kind M. Beaumé even

1352 Precipitated platina vitrified by M. Beaumé

fucceeded in melting the precipitate along with certain fluxes, into a vitriform fubftance by two different proceffes. The precipitate of platina, mixed with calcined borax, and a very fufible white glafs, was expofed, for 36 hours, in the hotteft part of a potter's furnace; and afforded a greenifh glafs, inclining to yellow, without globules of reduced metal. This glafs, treated a fecond time with cream of tartar, gypfum, and vegetable alkali, was completely melted, and exhibited globules of platina difperfed through its fubftance. M. Beaumé feparated them by wafhing, and found them ductile. The fame chemift afterwards, together

(A) For a particular account of this procefs fee before n° 587.

Platina.

gether with M. Macquer, expofed precipitate of platina to the fame burning mirror with which they had fufed the metal: the precipitate exhaled a very thick and luminous fume, with a ftrong fmell of aqua-regia: it loft its red colour, refumed that of platina, and melted into a perfect brilliant button, which was found to be an opaque vitreous fubftance, of an hyacinthine colour at its furface, and blackifh within; and may be confidered as a true glafs of platina. It may however be obferved, that the faline matters with which it was impregnated contributed doubtlefs to its vitrification.

"The orange-coloured precipitate obtained by pouring a folution of fal ammoniac into a folution of platina, appears to be a faline fubftance entirely foluble in water. This precipitate has a valuable property, difcovered by M. de l'Ifle, viz. that it is fufible without addition in a good furnace or common forge-heat. The platina melted by this procefs is a brilliant, denfe, and clofe-grained button; but it is not malleable unlefs it has been expofed to a very ftrong heat. Macquer thinks that this fufion, like that of the grains of platina alone, expofed to the action of a violent fire, confifts only in the agglutination of the foftened particles; which being exceedingly more divided and minute than the grains of platina, adhere to and touch each other in a greater number of points than the grains; and in that manner render the texture of the metal much more denfe, though no true fufion may have taken place. It feems, however, that if platina in grains be capable of fufion by the burning glafs, and of becoming confiderably ductile, the precipitate of this metal, formed by fal ammoniac may likewife be fufed on account of its extreme divifion; and that its not being as ductile as the button of platina fufed by the folar heat, may perhaps depend on its retaining a part of the matter it carried down with it in precipitation, of which it may be poffible to deprive it by fire."

1353 Precipitate by fal ammoniac fufible in a ftrong forge heat.

1354 This fufion fuppofed by Macquer not to be perfect.

1355 Attempts to purify platina by cupellation

It being fo extremely difficult to bring platina itfelf into fufion, one of the firft attempts to purify it was by cupellation with lead. Thus the bafer metals would be fcorified; and, running through the crucible along with the lead, leave the platina in as great purity as though it had been melted by itfelf. This operation, however, was found almoft equally difficult with the fufion of the metal by itfelf. Lewis failed in the experiment, though he applied the moft violent heat of the ordinary cupelling furnaces. The vitrification and abforption of the lead indeed took place as ufual; but in a fhort time the platina became fixed, and could not by any means be rendered fluid. Meffrs Macquer and Beaumé fucceeded by expofing an ounce of platina with two ounces of lead in the hotteft part of a porcelain furnace, where the fire is continued for 50 hours without intermiffion. At the end of the operation the platina was flattened in the cupel; its upper furface was dull and rough, and eafily feparated; but its under furface was brilliant, and it was found eafily to extend under the hammer; and on every chemical trial was found to be perfectly pure, without any mixture of lead. M. de Morveau likewife fucceeded in cupelling a mixture of one drachm of platina and two drachms of lead in M. Macquer's wind-furnace. The operation lafted eleven or twelve hours, and a button of platina was obtained which did not adhere to the cupel, was uniform, though rather rough, and of a colour refembling tin.' It weighed exactly one drachm, and was not at all acted upon by the magnet. Thus it appears that platina may be obtained in plates or laminæ, which may be forged, and confequently may be employed in making very valuable utenfils; and this the more efpecially as Mr Beaumé has obferved that different pieces of it may be welded and forged like iron. After having heated two pieces of pure cupelled platina to whitenefs, he placed them one upon the other, and ftriking them brifky with a hammer, found that they united together as quickly and firmly as two pieces of iron would have done.

Platina.

1356 Of the poffibility of adulterating gold with platina.

The great fpecific gravity of platina has rendered it a very defirable matter for fuch as wifh to adulterate the precious metal, and can procure the platina eafily. This, however, can only be done in South America, where platina is met with in plenty. In Europe the fcarcity of platina renders it a more valuable object than even the gold itfelf. Fears of this fraud, however, have undoubtedly given occafion to the prohibition of exporting it. There are great differences among chemifts concerning the quantity of platina that can be mixed with gold without deftroying the colour of the latter. Dr Lewis, as has already been obferved, informs us, that four parts of platina may be mixed with one of gold, and yet the mixture be no paler than that for guineas; while Fourcroy afferts, that "it greatly alters the colour of the metal, unlefs its quantity be very fmall: thus, for example, a 47th part of platina, and all the proportions below that, do not greatly affect the colour of the gold." But whether this be the cafe or not, chemiftry has afforded various ways of feparating even the fmalleft proportion of platina from gold; fo that there is now no reafon to prohibit the importation of it to Europe, more than that of any other metal with which gold can be alloyed. The following are the methods by which the platina may be moft readily difcovered: 1. By amalgamating the fufpected metal with mercury, and grinding the mixture for a confiderable time with water; by which the platina will be left, and the gold remain united with the quickfilver. 2. By diffolving a little of it in aqua-regia, and precipitating with alkaline falt; the remaining liquor, in cafe the metal has been adulterated with platina, will be fo yellow, that it is fuppofed a mixture of one thoufandth part would thus be found out. 3. By precipitation with fal ammoniac, which throws down the platina but not the gold. If mineral alkali be ufed, the gold will be precipitated, but not the platina, unlefs the precipitant is in very large quantity. 4. By precipitation with green vitriol, which throws down the gold, and leaves the platina united with the menftruum.

1357 Methods of detecting this fraud if it fhould be practifed.

1358 Platina moft eafily difcoverable by its great fpecific gravity.

All thefe methods, however, are not only attended with a confiderable deal of trouble, but in fome cafes, for inftance in fufpected coin, it might not be eligible to ufe them. The hydroftatic balance alone affords a certain method of difcovering mixtures of metals without hurting the texture of their parts. The great fpecific gravity of platina would very readily difcover it if mixed with gold in any moderate quantity; and even in the fmalleft, the gravity of the mafs could never be lefs than that of the pureft gold: which circumftan

cumfta n

cumſtance alone, as gold is never worked without alloy, would be ſufficient to create a juſt ſuſpicion: after which ſome of the methods already mentioned might be tried. It is poſſible, however, that the hardneſs and ductility of platina might render it more proper for alloying gold than even copper or ſilver, uſually made uſe of for this purpoſe.

§ 15. *Of Manganese.*

1359 New ſemimetal afforded by mangane∫e.

THIS ſubſtance is now diſcovered to afford a ſemimetal different from all others, and likewiſe to poſſeſs ſome other properties of a very ſingular kind. Mr Scheele has inveſtigated its nature with the utmoſt care; and the reſult of his inquiries are as follows:

1360 Properties of the common mangane∫e treated with vitriolic acid.

1. Two drachms of levigated mangane∫e, digeſted for ſeveral days in a diluted vitriolic acid, did not appear to be diſſolved or diminiſhed in quantity; nevertheleſs a yellowiſh white precipitate was procured by ſaturating the acid with fixed alkali. The remaining mangane∫e was not acted upon by more of the ſame acid, but the addition of another half ounce nearly deſtroyed the acidity of the menſtruum when boiled upon it.

2. With concentrated vitriolic acid an ounce of mangane∫e was reduced to a maſs like honey, and then expoſed to the fire in a retort till it became red-hot. Some vitriolic acid came over into the receiver; and after breaking the retort, a maſs was found in it weighing $12\frac{1}{4}$ drachms, hard and white in the inſide, but red on the outſide. A great part of it diſſolved in diſtilled water, on the affuſion of which at firſt it became very hot. The reſiduum after edulcoration weighed a drachm and an half, and was of a grey colour. Being calcined in a crucible with concentrated vitriolic acid till no more vapours aroſe, it was all diſſolved by water excepting one drachm; which being again calcined with the ſame acid, an inſoluble reſiduum of a white colour, and weighing only half a drachm, remained. This white reſiduum effervefced with borax, and melted into a tranſparent brown glaſs; it likewiſe effervefced with fixed alkali, changing into a brown maſs, which yielded an hepatic ſmell with acids, and became at the ſame time gelatinous. The ſolution obtained by calcination was evaporated and ſet to cryſtallize. A few ſmall cryſtals of ſelenite were firſt depoſited, and afterwards ſome very fine large cryſtals of an oblique parallelopiped form, whoſe number increaſed as long as there was any liquid left. They taſted like Epſom ſalt, and Mr Weſtfeld ſuppoſes them to be alum; but according to Mr Scheele, they have no other reſemblance to alum than that they contain the vitriolic acid.

1361 Entirely diſſolved by phlogiſticated vitriolic acid.

3. By phlogiſticated vitriolic acid the mangane∫e was entirely diſſolved. To procure this acid in purity, Mr Scheele dipped ſome rags in a ſolution of alkali of tartar, and after ſaturating them with the fumes of burning brimſtone, put them into a retort, pouring on them ſome diſſolved acid of tartar, luting on a receiver which contained levigated mangane∫e and water. After a warm digeſtion of only one day, the liquid of the receiver had become as clear as water, and a little fine powder, conſiſting principally of ſiliceous earth, fell to the bottom.

4. Two drachms of levigated mangane∫e, digeſted for ſeveral days with an ounce of pure colourleſs acid of nitre, did not appear to have deprived the menſtruum of its acidity, or to have been affected by it in any degree. The liquor being diſtilled off, and the product of the diſtillation poured back on the reſiduum, a ſmall quantity of it was diſſolved. By a third diſtillation, and pouring back the liquor on the reſiduum, a complete ſolution was effected; and thus quantity of acid appeared capable of diſſolving nine drachms of the powder.

1362 Precipitate and cryſtals obtained from the ſolution.

5. The ſolution of mangane∫e thus ſaturated, was filtered and divided into two equal portions. Into one of theſe ſome drops of vitriolic acid were poured, by which a fine white powder was thrown down, which, however, did not ſettle to the bottom for ſome hours. It was ſoluble neither in boiling water nor in acids. The limpid ſolution, by evaporation, yielded ſome ſmall cryſtals of ſelenite or gypſum.

6. From the other half of this ſolution, after evaporation by a gentle heat, about ten grains of ſmall ſhining cryſtals of a bitter taſte were obtained. On pouring ſome drops of vitriolic acid into the ſolution inſpiſſated by gentle heat, no precipitation, excepting of a little ſelenite, enſued; but as ſoon as it was inſpiſſated to the conſiſtence of honey, ſome fine acicular cryſtals, verging towards the ſame centre, began to form, but grew ſoft, and deliqueſced in a few days after.

1363 Mangane∫e diſſolved by phlogiſticated nitrous acid.

7. Phlogiſticated nitrous acid diſſolves mangane∫e as readily as the phlogiſticated vitriolic. A little levigated mangane∫e mixed with ſome water was put into a large receiver, to which a tubulated retort was luted. Some ounces of common nitrous acid were put into the retort, to which ſome iron-filings were added, taking care always to cloſe the orifice with a glaſs ſtopple. The phlogiſticated nitrous acid thus paſſed over into the receiver, and diſſolved the mangane∫e in a few hours: the ſolution was as limpid as water, excepting only a little fine ſiliceous earth. Another white precipitate, ſimilar to that produced by adding vitriolic acid to the ſolution in pure nitrous acid now began to fall; but in other reſpects this ſolution agreed with the former.

1364 Effects of it on ſpirit of ſalt.

8. An ounce of purified muriatic acid was poured upon half an ounce of levigated mangane∫e; which, after ſtanding about an hour, aſſumed a dark brown colour. A portion of it was digeſted with heat in an open glaſs veſſel, and ſmelled like warm aqua-regia. In a quarter of an hour the ſmell was gone, and the ſolution became clear and colourleſs. The reſt of the brown ſolution being digeſted, to ſee whether the muriatic acid would be ſaturated with mangane∫e, an effervefcence enſued, with a ſtrong ſmell of aqua-regia, which laſted till next day, when the ſolution was found to be ſaturated. Another ounce of acid was poured upon the reſiduum, which was followed by the ſame phenomenon, and the mangane∫e was entirely diſſolved, a ſmall quantity of ſiliceous earth only remaining. The ſolution, which was yellow, being now divided into two portions, ſome drops of vitriolic acid were poured into the one, by which it inſtantly became white, and a fine powder, inſoluble in water, was precipitated. Some ſmall cryſtals of ſelenite were formed by evaporation, and the reſiduum exhibited the ſame phenomenon with thoſe abovementioned with nitrous

1365 Entirely diſſolved by this acid.

Manganese

trous acid, by evaporating the other half, some small shining angular crystals were obtained, similar to those procured by means of the nitrous acid.

1366 Scarce soluble in fluor acid,

9. Very little manganese was dissolved by fluor acid, even after several days digestion. A great quantity was required to form a saturated solution. It had very little taste, and gave a small quantity of precipitate with fixed alkali. But if a neutral salt, composed of fluor acid and sal ammoniac, be added, a double decomposition takes place, and the manganese is precipitated along with the fluor acid.

1367 Or in phosphoric acid.

10. A drachm of phosphoric acid, digested with as much powdered manganese, dissolved but litle of it; and, though evaporated to dryness, the residuum tasted very acid; but by adding more manganese the acid was at last saturated. On adding microcosmic salt to a solution of manganese, a decomposition takes place similar to that effected by the combination of fluor acid and volatile alkali.

1368 Partly soluble in acid of tartar.

11. Pure acid of tartar dissolved manganese partly in the cold, and more effectually by means of heat. The whole, however, could not be dissolved, though the acid was at last saturated by adding a great quantity of the mineral. On adding a solution of soluble tartar, a double decomposition took place.

1369 With difficulty in the acetous.

12. Little was dissolved by distilled vinegar, though boiled on manganese; but after distilling spirit of verdigris several times upon it, the acid at last became saturated. The solution, evaporated to dryness, left a deliquescent mass. Little or none of the remaining manganese was dissolved by concentrated vinegar, though repeatedly distilled upon it.

1370 Entirely dissolved by acid of lemons;

13. With acid of lemons the whole was dissolved with effervescence, excepting only some white earth.

1371 And by water impregnated with fixed air.

14. Water impregnated with fixed air likewise dissolved manganese, but parted with it on the addition of alkali, or spontaneously by exposure to the air.

1372 Has a strong attraction for phlogiston.

From these experiments Mr Scheele concludes, that manganese has a strong elective attraction for all phlogistic substances; and that this attraction becomes stronger, if there be present a menstruum which can unite with the phlogisticated manganese. Thus it attracts phlogiston more powerfully than even the nitrous acid itself in the moist way.

1373 Becomes white by saturation with phlogiston.

By saturation with phlogiston, manganese has the property of losing its black colour, and assuming a white one, which is unusual, the phlogiston generally communicating a black or dark colour to the substances with which it was united.

1374 Contains some phlogiston naturally.

That manganese naturally contains some phlogiston, though but in small quantity, appears from evaporating a solution of it in vitriolic acid to dryness, and then distilling the mass in a glass retort in an open fire. When the retort begins to melt, the acid parts fly off from the manganese in a sulphureous state, leaving the former of its natural black colour. By distilling the mass remaining after evaporation of the nitrous solution, a green volatile nitrous acid remains, and the black calx of manganese remains as before.

1375 Becomes insoluble in pure acids by losing its phlogiston.

A solution of this mineral in vitriolic or nitrous acid, precipitated by fixed alkali, retains its colour; but when calcined in the open fire, again becomes black.

By losing its phlogiston, manganese becomes insoluble in pure acids; and therefore the residuum of the

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abovementioned distillations cannot be dissolved by adding more of the vitriolic or nitrous acids: but if that which has come over into the receiver be poured back into the retort, a solution will again take place by reason of the manganese reassuming the phlogiston it had parted with to the acid.

1376 Partial solutions of manganese explained on this principle.

On this principle our author explains the reason of the partial solutions of this mineral abovementioned. Part of it is dissolved, for instance, in the vitriolic acid, while the remainder is found insoluble. This happens (says he), "because the undissolved portion has parted with the little phlogiston it naturally possessed to that portion of manganese which is taken up by the vitriolic acid during the first digestion; for without that principle it is insoluble."

Manganese attracts phlogiston more strongly when combined with some acid than by itself, as appears from the following experiments.

1377 Strong attraction of manganese when combined with acids for phlogiston.

1. Levigated manganese, digested or boiled with a solution of sugar, honey, gum arabic, hartshorn, jelly, &c. remains unchanged; but on mixing the pounded mineral with diluted vitriolic, or pure nitrous acid, and then adding some of these substances, the whole is dissolved, the black colour vanishes by degrees, and the solution becomes as limpid as water. So strong is the attraction of manganese for phlogiston in these circumstances, that metals, the noble ones not excepted, render it soluble in these acids in a limpid form.

1378 Why the concentrated acid of vitriol dissolves manganese without addition.

Concentrated vitriolic acid, indeed, dissolves manganese entirely without any phlogiston. "It would be difficult (says Mr Scheele) to comprehend whence the phlogiston in this case should come, if we were not certain that several substances, which have a great attraction for phlogiston, can attract it in a red heat. Quicksilver and silver, when dissolved in the purest nitrous acid, really lose their phlogiston, which is a constituent part of these metals. This appears from the red vapours in which the acid arises; and the dissolved metallic earth cannot be again reduced to its metallic form, till it has acquired the lost phlogiston, which is effected either by precipitation with complete metals or by heat alone. Thus manganese can attract the quantity of phlogiston necessary for its solution by means of concentrated vitriolic acid from heat. It is not probable that the concentrated acid undergoes a decomposition in this degree of fire; for if you saturate half an ounce of this acid with alkali of tartar, and afterwards calcine in a retort, with a receiver applied, an ounce and a half of powdered manganese, with an equal quantity of the same vitriolic acid, then dissolve the calcined mass in distilled water, and likewise wash well the receiver, which contains some drops of vitriolic acid, which are also to be added to the solution, and lastly, add the same quantity of alkali, there will be no mark of superabundant acid or alkali. Thence it may be concluded, that the phlogiston in the vitriolic acid, if there really exists any in it, contributes nothing to the solution. But the manganese precipitated by alkali, contains a considerable quantity of it; in consequence of which it is afterwards entirely soluble in acids without any addition.

1379 Why the volatile sulphureous acid dissolves it.

"The effects of volatile sulphureous acid on manganese, clearly prove what has been asserted. The manganese attracts the phlogiston contained in this acid, which is the cause of its great volatility, and which

renders

Manganeſe

renders the former ſoluble in the new pure vitriolic acid. If this ſolution be mixed with concentrated vitriolic acid and diſtilled, no volatile ſulphureous acid is obtained: and if it be precipitated by means of fixed vegetable alkali, vitriolated tartar is obtained; which proves that manganeſe has a ſtronger attraction than vitriolic acid for phlogiſton in the moiſt way.

1380 Effects of nitrous acid on mangeneſe explained.

"The effects of nitrous acid on this ſubſtance are ſimilar to thoſe of vitriolic acid. Could ſpirit of nitre ſuſtain as great a degree of heat as the concentrated vitriolic acid, it would alſo entirely diſſolve the manganeſe by means of the phlogiſton attracted by heat; but as this is not the caſe, it is neceſſary to add phlogiſton in the manner abovementioned. The manganeſe decompoſes phlogiſticated nitrous acid, for the ſame reaſon that it does the volatile ſulphurcous acid; and that the phlogiſton of this acid really combines with manganeſe, is manifeſt from this, that the affuſion of vegetable acid produces no ſmell of aquafortis by diſplacing the phlogiſticated acid of nitre. By diſtillation with pure vitriolic acid alſo, the nitrous acid is expelled, not in a ſmoking ſtate, and of a yellow colour, but pure and colourleſs.

"In the ſolution of manganeſe by means of gum arabic or ſugar, a very conſiderable efferveſcence takes place, owing to the extrication, or probably rather the production, of fixed air from the mixture; but with phlogiſticated acid of nitre no ſuch phenomenon takes place, becauſe the manganeſe is combined with pure phlogiſton; and if this ſhould be again ſeparated, there is no cauſe for the production of fixed air. This mineral is alſo diſſolved without efferveſcence, by uniting it with nitrous acid and metals, arſenic or oil of turpentine."

1381 Exiſtence of phlogiſton in the muriatic acid proved

As muriatic acid diſſolves manganeſe without addition, Mr Scheele is of opinion that this proves the exiſtence of phlogiſton in that acid, as has already been taken notice of. The manganeſe digeſted in the cold with ſpirit of ſalt aſſumes a dark brown colour; for it is a property of this ſubſtance that it cannot be diſſolved into a colourleſs liquor without phlogiſton, but has always a red or blue colour; but with ſpirit of ſalt the ſolution is more brown than red, on account of the fine particles of the manganeſe floating in the liquid. Here the mineral adheres but looſely to the acid, ſo that it may be precipitated by water.

1382 Explanation of the action of acid of tartar and acid of lemons.

The effects of acid of tartar and acid of lemons upon manganeſe are likewiſe explained on the principle already laid down, *viz.* the extreme attraction this ſubſtance has for phlogiſton. Thus it attracts part of that naturally contained in theſe acids, decompoſing one part of them, and being diſſolved by the other. This deſtruction of the acid is ſimilar to that of the ſugar, gum arabic, &c. which render it ſoluble in nitrous acid; for if a proper quantity of theſe are added, the manganeſe will be diſſolved, without a poſſibility of recovering the ſmalleſt particle of the vegetable ſubſtance employed; and if the ſolution be ſlowly evaporated and calcined, there will not remain the ſmalleſt mark of burned ſugar or gum. During this decompoſition, a pungent vapour ariſes, which, being collected, appears to be true vinegar. It is obtained in its pureſt ſtate from diluted vitriolic acid, ſugar, and manganeſe.

1383 Of fluor acid.

Fluor acid diſſolves but very little manganeſe, owing to its precipitating ſalt which envelopes the particles of manganeſe, and prevents the further action of the menſtruum. In all precipitations of manganeſe, however, by means of mild fixed alkalies, the full quantity is not procured; becauſe the fixed air, detached from the mineral, diſſolves part of it.

1384 Effects of manganeſe on nitre.

Though manganeſe decompounds nitre, yet this does not happen till the mixture becomes red hot. If phlogiſticated manganeſe be mixed with an equal quantity of nitre, and diſtilled in a glaſs retort, the mixture begins to grow black before the retort becomes red-hot, but no nitrous acid goes over. By lixiviation, no mark of uncombined alkali is met with; but phlogiſticated nitrous acid is extricated by the application of tamarinds, or any vegetable acid. Three parts of phlogiſticated manganeſe, mixed with one part of finely pounded nitre, yields no nitrous acid, though the nitre is alkalized as ſoon as the mixture becomes black in the retort.

1385 Experiments on manganeſe united with phlogiſton.

Mr Scheele proceeds now to another ſet of experiments upon manganeſe united with phlogiſton. In order to procure it in this ſtate, the beſt method is to diſſove in diſtilled water, and cryſtallize the ſalt obtained by ſolution of manganeſe in vitriolic acid, and then precipitate it with vegetable fixed alkali. In this ſtate it is white like chalk: but by calcination in an open fire, the ſuperfluous phlogiſton flies off, and the calx regains its uſual black colour. This change of colour likewiſe happens when the precipitation is made with cauſtic alkalies, whether fixed or volatile. The precipitate, indeed, in this caſe, is white when kept cloſe from the air, but aſſumes a brown colour when expoſed to it for any time: But when the precipitation is made by mild alkali, the white colour is preſerved by the fixed air, which in this caſe it alſo contains. By diluting the ſolution with a conſiderable quantity of water, and precipitating with cauſtic alkali, the precipitate is brown from the very beginning, owing to the air in the liquid attracting the phlogiſton from the manganeſe. The precipitate formed by lime-water is alſo brown; but on adding more of a ſtrong ſolution of manganeſe, and afterwards precipitating with cauſtic alkali, the powder falls of a white colour; becauſe the air, being already ſaturated with phlogiſton, cannot take up any more. The reſults of Mr Scheele's experiments on this phlogiſticated manganeſe are,

1386 By diſtillation *per ſe.*

1. An ounce of this ſubſtance diſtilled by itſelf in a glaſs retort, with a ſtrong fire, yielded a great quantity of fixed air with ſome drops of water. The reſiduum poured warm out of the retort grew red-hot, and ſet the paper on fire.

2. On repeating the experiment with only a drachm of phlogiſticated manganeſe, and tying a bladder to the neck of a retort, three ounce-meaſures of air came over: the reſiduum was of a light grey colour; diſſolved in acids without addition of any more phlogiſton; and took fire in that degree of heat in which ſulphur ſmokes, but does not burn. From theſe experiments, ſays Mr Scheele, it is evident, that phlogiſton does not ſeparate from manganeſe if the acceſs of air be prevented.

1387 Boiled with oil olive.

3. One part of finely powdered manganeſe boiled in four of oil-olive, efferveſced violently, and diſſolved into a kind of ſalve.

1388 By diſtillation with charcoal.

4. On diſtilling a mixture of finely powdered manganeſe and charcoal, with an empty bladder tied to the mouth of the retort, a quantity of fixed air was extricated

Manganese.

cated when the retort began to melt and distended the bladder." The residuum was mostly soluble in diluted vitriolic acid.

1389 With sulphur.

5. On distilling half an ounce of powdered manganese with two drachms of sulphur, the latter partly rose into the neck of the retort, and some volatile acid vapours penetrated through the lute. The distillation was continued till the retort began to melt; and, on cooling, the residuum was found to weigh $5\frac{1}{4}$ drachms. It was of a yellowish-grey colour; and dissolved in spirit of vitriol with effervescence, yielded an hepatic smell, some sulphur being also precipitated at the same time. By calcination in the open air, the sulphur was dissipated; but great part of the mass was rendered soluble on account of its having been penetrated by the acid vapour, and shot into crystals as though it had been formally dissolved in volatile sulphureous acid; and by repeating the calcination with more sulphur, the whole became at last entirely soluble, and was reduced to crystals.

1390 By calcination with nitre.

Finely powdered manganese, triturated with nitre and strongly calcined in a crucible, unites with the alkali of the nitre, while the acid is dissipated in the air. The mass formed by the union of the manganese and alkali is of a dark green colour, and soluble in water, communicating also a green colour to the liquid; but in a short time a fine yellow powder (an ochre of iron) falls to the bottom, leaving the liquor of a blue colour. By the addition of water, this solution first assumes a violet colour, grows afterwards red, and a precipitation of the manganese takes place, which resumes its natural colour as soon as it has fallen. The same precipitation takes place on the addition of a few drops of acid, or by exposure for some days to the open air. As for the dark red colour assumed by the solution when the precipitate is about to fall, Mr Scheele conjectures that the particles of manganese may naturally have a red colour, which becomes visible when the substance is dispersed through a menstruum without being perfectly dissolved.

1391 With the addition of arsenic.

7. By the addition of finely powdered white arsenic to the alkaline mass of nitre and manganese, the green colour disappears, and the whole becomes white; phlogisticated manganese being also precipitated on the addition of water. This arises from the more powerful attraction of manganese for the phlogiston of the arsenic than that of the arsenical acid itself; and for the same reason, if the mass be calcined with charcoal, or any other phlogistic substance, a colourless solution will be obtained.

1392 By distillation with sal ammoniac.

8. Half an ounce of phlogisticated manganese, distilled in a retort with an equal quantity of powdered sal ammoniac, yielded first a concrete volatile salt, after which some sal ammoniac undecomposed arose in the neck of the retort. Half an ounce of pure dephlogisticated manganese, mixed with two drachms of powdered sal ammoniac, yielded alkali in its caustic state. Both residuums were soluble in water; which shows that manganese attracts phlogiston from the volatile alkali.

1393 By distillation with pure nitrous acid.

9. On digesting finely powdered manganese for some weeks with pure nitrous acid and some volatile alkali, a great number of air-bubbles rise to the top, and the volatile alkali is entirely decomposed: for though the mixture be afterwards distilled in a retort with the addition of quicklime, not the least urinous smell can be perceived. This decomposition is effected by the manganese attracting the phlogiston of the volatile alkali; for that the nitrous acid has no share in this, is proved by the following experiment.

Manganese.

1394 Volatile alkali destroyed by manganese attracting its phlogiston.

10. An ounce of well triturated manganese was distilled with half an ounce of sal ammoniac; and a liquid alkali, such as that obtained from sal ammoniac and quicklime, was procured. On repeating this experiment, with the variation only of a bladder instead of a receiver, the same kind of air was obtained as that which rises to the top of the nitrous mixture. Though the emission of this air indicated a destruction of the volatile alkali, our author explains the reason of its being still obtained in a caustic state by the phlogiston taken from the alkali being more than sufficient to render the alkali soluble in muriatic acid; in consequence of which, the superfluous quantity combines with the manganese, and enables it to decompose the sal ammoniac in the ordinary way. It must be owned, however, that his reasoning on this subject is not entirely satisfactory, nor does the account he gives of his experiments seem entirely consistent with itself. See *Scheele's Chem. Essays*, Essay V. § xxxix.

1395 By distillation with arsenic.

11. Powdered manganese, distilled with an equal quantity of white arsenic, underwent no change, the arsenic flying off in its proper form; but with an equal quantity of yellow orpiment, some volatile sulphureous acid came over first, then a yellow sublimate, and at last a little red sublimate arose. On augmenting the fire by degrees, the orpiment remained obstinately attached to it. Similar effects ensued on treating manganese with an equal quantity of antimony; which likewise yielded a pungent sulphureous acid, but no sublimate. By calcination in the open air these compounds are decomposed; and the manganese, united with vitriolic acid, becomes soluble in water.

1396 With cinnabar.

12. On distilling manganese with an equal quantity of finely pounded cinnabar, a volatile sulphureous acid came over first; then a little cinnabar was sublimed into the neck of the retort; and at last the quicksilver, which had been the basis of the cinnabar, began to distil: the residuum, being a combination of manganese and sulphur, was similar to the compounds already described.

1397 With corrosive sublimate.

13. With an equal quantity of corrosive sublimate, manganese underwent no change; but when sublimed with an equal quantity of mercurius dulcis, a corrosive sublimate, and then mercurius dulcis, arose into the neck of the retort. The reason of this is, that the mercurius dulcis contains a portion of phlogiston; by being deprived of which it ceases to be mercurius dulcis, and becomes corrosive sublimate: but by reason of the strong attraction of manganese for phlogiston, the mercurius dulcis parts with that portion which is necessary to keep it in its mild state, and thus is converted into corrosive mercury.

Sect. IV. *Inflammable Substances.*

1398 General division.

These may be divided into the following classes: 1. Sulphurs. 2. Ardent spirits. 3. Oils and fats. 4. Resins. 6. Bitumens; and, 6. Charcoal.

§ 1. Sul-

§ 1. Sulphurs.

1399 Sulphur.

1. *Common ſulphur.* For the extraction of this ſubſtance from its ores, ſee Sulphur. The artificial compoſition of it we have already related, nº 715; and have now only to take notice of a very few of its properties, which come more properly under this ſection.

Sulphur, as commonly uſed in commerce and the arts, is of a pale yellow colour, of a diſagreeable and peculiar ſmell, which is rendered more ſenſible when it is heated or rubbed. By rubbing, it receives very curious electrical qualities: (See Electricity.) Its ſpecific gravity is conſiderably greater than that of water, though leſs than earths or ſtones. In cloſe veſſels, ſulphur is incapable of receiving any alteration. It melts with a very gentle heat; and then is ſublimed, adhering to the capital in ſmall, very fine, needle-like cryſtals, called *flowers of ſulphur.* It may thus be ſub-

1400 Cryſtallization.

limed many times without alteration. If ſulphur is expoſed to a heat barely ſufficient to melt it, and very ſlowly cooled, it cryſtallizes in form of many needles croſſing one another. Some of theſe pointed cryſtals may alſo be obſerved in the interior parts of the lumps of ſulphur which have been melted, and caſt into cylyndrical moulds, as they are commonly ſold; becauſe the centre of theſe cylindrical rolls is more ſlowly cooled than the ſurface. Sulphur alſo gives this needle-like form to cinnabar, antimony, and many other minerals containing it. Sulphur may be decompoſed in ſeveral ways. The moſt ſimple is by burning; which we have already taken notice of, nº 623. It may alſo be very effectually decompoſed by mixing it with iron filings and water. In this caſe the phlogiſton is diſſipated, and the acid uniting with the iron forms a green vitriol.

1401 Decompoſed by a ſuperabundance of phlogiſton.

It is very remarkable, that though ſulphur is compoſed of vitriolic acid and phlogiſton, yet the addition of more inflammable matter, ſo far from making the union ſtronger, weakens it to a great degree: and hence we have another method of decompoſing this ſubſtance; namely, by combining it with a large quantity of oil, and diſtilling the compound.

Sulphur is capable of being eaſily diſſolved in expreſſed oils, but very difficultly in eſſential ones. Theſe compoſitions are called *balſams of ſulphur;* and are ſometimes employed in medicine, but are found to be of a very heating nature. They are much uſed by farriers. According to Mr Beaumé, ſulphur cannot be diſſolved in oil, without a heat ſufficient to melt it. A larger quantity is kept diſſolved when the mixture is hot, than when cold; and conſequently the ſulphur, eſpecially if it has been diſſolved in a thin eſſential oil, cryſtallizes on cooling the mixture. The ſulphur, thus ſeparated from the oil, is found not to be altered in any reſpect from what it formerly was; but if the mixture is expoſed to a degree of heat capable of entirely decompoſing the oil, the ſulphur is decompoſed along with it, and the ſame products are obtained by diſtilling this mixture to dryneſs, as if a mixture of pure oil of vitriol and oil were diſtilled. Theſe products are, firſt a portion of oil, when an eſſential oil was made uſe of in the compoſition of the balſam; then ſome volatile ſulphureous acid, which is at firſt watery, and afterwards becomes ſtronger; along with this acid more oil ariſes, which becomes more and more thick towards the end of the diſtillation; and laſtly, when the retort has been made red hot, nothing remains but a fixed coal.

In this proceſs we find, that both the ſulphur and oil are decompoſed. The acid of the ſulphur ſeems to attack the watery principle of the oil, while its phlogiſton remains confounded with that of the oil, or is diſſipated in vapours. Hence, though the vitriolic acid in ſulphur is concentrated to the utmoſt degree, and perfectly free from water, what riſes in this diſtillation is very aqueous, by reaſon of the water which it attracts from the oil. 1402

How ſoluble in ſpirit of wine.

Spirit of wine does not ſenſibly act upon ſulphur in its liquid ſtate; but if both the ſpirit of wine and ſulphur meet in the ſtate of vapour, they will then unite, and a perfect ſolution will take place. By methods of this kind, many combinations might be effected, which have been hitherto thought impoſſible. 1403

Its union with metals.

Pure ſulphur unites eaſily with all metals; gold, platina, and zinc, excepted. The compounds, except that with mercury, poſſeſs a metallic luſtre without any ductility. The ſulphur may be ſeparated by expoſing the mixture to a ſtrong fire. (See Metallurgy,) or by diſſolving the metalline part in acids. The ſulphur, however, defends ſeveral of the metals from the action of acids; ſo that this diſſolution ſucceeds but imperfectly. The reguline part of antimony is more eaſily ſeparated from ſulphur by means of acids than by any other metalline ſubſtance. Alkaline ſalts will ſeparate the ſulphur from all metals in fuſion, but they unite with it themſelves, and form a compound equally capable of diſſolving the metal. 1404

Vermilion

Sulphur united with quickſilver forms the beautiful pigment called *cinnabar*, or *vermilion;* which is ſo much uſed in painting, that the making of it is become a diſtinct trade. Neumann relates, that in the making of cinnabar by the Dutch method, ſix or eight parts of quickſilver are made uſe of to one of ſulphur. The ſulphur is firſt melted, and then the quickſilver is ſtirred into it; upon which they unite into a black maſs. In this part of the proceſs the mixture is very apt to take fire; of which it gives notice by ſwelling up to a great degree. The veſſel muſt then be immediately covered. The maſs being beaten to powder, is afterwards to be ſublimed in large earthen jars almoſt of an equal wideneſs from end to end; theſe are hung in a furnace by a ſtrong rim of iron. When the matter is put in, the mouth of the veſſel is covered, the fire increaſed by degrees, and continued for ſeveral hours, till all the cinnabar has ſublimed; care being taken to introduce at times an iron rod to keep the middle clear; otherwiſe the cinnabar concreting there, and ſtopping up the paſſage would infallibly burſt the veſſels.

The quantity of ſulphur directed in the common receipts for making cinnabar is greatly larger than the above; being no leſs than one third of the quantity of quickſilver employed: accordingly it has been found, that the ſublimate, with ſuch a large quantity of ſulphur, turned out of a blackiſh colour, and required to be ſeveral times ſublimed before it became perfectly red; but we cannot help thinking, that by one gentle ſublimation

Sulphur. sublimation the superfluous sulphur might be separated, and the cinnabar become perfectly pure the second time. Hoffman gives a curious method of making cinnabar without sublimation: by shaking or digesting a little mercury with volatile tincture of sulphur, the mercury readily imbibes the sulphur from the volatile spirit, and forms with it a deep red powder, not inferior in colour to the cinnabar prepared in the common manner. Dr Lewis has found the common solutions of sulphur by alkalies, or quicklime, to have a similar effect. This cinnabar will likewise be of a darker or lighter colour, according as the solution contains more or less sulphur.

1405 Pulvis fulminans.

Sulphur is a principal ingredient in gun-powder, (see GUN-POWDER.) It also enters the composition of the *pulvis fulminans*. This consists of three parts of nitre, two of the dry alkali of tartar, and one part of sulphur, well ground together. If a little quantity of this powder is laid on an iron-spoon or shovel, and slowly heated, it will explode, when it arrives at a certain degree of heat, with astonishing violence and noise. The most probable opinion concerning this is, that the fixed air contained in the alkali is, by the acid vapours acting upon and endeavouring to expel it all at once, driven off with such force, that a loud explosion is produced.

1406 Phosphorus of urine.

2. *Phosphorus of Urine*. This is a very inflammable substance, composed of phlogiston united with a certain acid, the properties of which we have already taken notice of, n° 904 *et seq*. The preparation of it was long a secret, and only perfectly discovered by Mr Margraaf, who published it in the Berlin Memoirs in 1743. This process being by far the best and most practicable, we shall content ourselves with inserting it alone.

1407 Mr Margraaf's process for making.

Two pounds of sal ammonaic are to be accurately mixed with four pounds of minium, and the mixture distilled in a glass retort; by which means a very penetrating, caustic alkaline spirit will be obtained. The residuum, after the distillation, is a kind of *plumbum corneum*; n° 812. This is to be mixed with nine or ten pounds of extract of urine, evaporated to the consistence of honey. (Seventy or eighty gallons of urine are required to produce this quantity of extract.) The mixture is to be made slowly in an iron pot set over the fire, and the matter frequently stirred. Half a pound of powdered charcoal is then to be added, and the evaporation continued till the whole is reduced to a black powder. This powder is to be put into a retort, and urged with a graduated heat, till it becomes red hot, in order to expel all the volatile alkali, fetid oil, and ammoniacal salt, that may be contained in the mixture. After the distillation, a black friable residuum remains, from which the phosphorus is to be extracted by a second distillation and a stronger heat. Before it is subjected to another distillation, it may be tried by throwing some of it upon hot coals. If the matter has been well prepared, a smell of garlic exhales from it, and a blue phosphorical flame is seen undulating along the surface of the coals.

The matter is to be put into a good earthen retort, capable of sustaining a violent fire. Three quarters of the retort are to be filled with the matter which is to yield the phosphorus, and it is to be placed in a furnace capable of giving a strong heat. Mr Margraaf divides the matter among six retorts, so that if any accident happens to one, the whole matter is not lost. The retorts ought to be well luted to a receiver of a moderate size, pierced with a small hole, and half full of water; and a small wall of bricks must be raised between the furnace and receiver, in order to guard this vessel against heat as much as possible. The retorts are to be heated by slow degrees for an hour and an half; then the heat is to be increased till the vessels are red hot, when the phosphorus ascends in luminous vapours. When the retort is heated till between a red and white, the phosphorus passes in drops, which fall and congeal in the water at the bottom of the receiver. This degree of heat is to be continued till no more comes over. When a retort contains eight pints or more, this operation continues about five hours.

1408 Rectification of phosphorus.

In the first distillation, phosphorus never passes pure, but is always of a blackish colour, by reason of its carrying along with it some part of the coal. From this, however, it may be purified by rectification in a small glass-retort, to which is luted a receiver half full of water. A very gentle heat is sufficient; because phosphorus, once formed, is very volatile; and as the fuliginous matter was raised probably by the fixed air emitted by the charcoal in the instant of its union with the phosphorine acid, none of it can arise in a second distillation.

The phosphorus is then to be divided into small cylindrical rolls, which is done by putting it in glass-tubes immersed in warm water; for the phosphorus is almost as fusible as suet. It takes the form of the glass-tubes; from which it may be taken out, when it is cold and hardened. This must be done under water, least the phosphorus should take fire.

1409 Process sometimes dangerous.

This concrete continually appears luminous in a dark place; and by a very slight heat takes fire, and burns far more vehemently than any other known substance. Hence it is necessary to be very cautious in the distillation of it; for if the receiver should happen to break while the phosphorus is distilling, and a little flaming phosphorus fall upon the operator's legs or hands, it would burn its way to the bone in less than three minutes. In this case, according to Mr Hellot, nothing but urine will stop its progress.

Though phosphorus takes fire very readily by itself, it does not inflame at all by grinding it with other inflammable bodies, as camphor, gun-powder, or essential oils. In grinding it with nitre, some luminous flashes are observed; but the mixture never burns, unless the quantity of phosphorus be large in proportion to the nitre: rubbed pretty hard on a piece of paper or linen, it sets them on fire if they are rough, but not if they are smooth. It fires written paper more readily than such as is white, probably from the former having more asperities. On grinding with iron-filings, it presently takes fire.

1410 Liquid phosphorus.

Oils ground with phosphorus appear, like itself, luminous in a temperately warm place; and thus become a liquid phosphorus, which may be rubbed on the hands, &c. without danger. Liquid phosphorus is commonly prepared by grinding a little of the solid phosphorus with oil of cloves, or rubbing it first with camphor, and this mixture with the oil. A luminous *amalgam*, as it is called, may be obtained, by digesting

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a ſcruple of ſolid phoſphorus with half an ounce of oil of lavender, and, when the phoſphorus begins to diſſolve and the liquor to boil, adding a drachm of pure quickſilver; then briſkly ſhaking the glaſs for five or ſix minutes till they unite.

1411 Experiments on phoſphorus with ſpirit of wine.

Rectified ſpirit of wine, digeſted on phoſphorus, extracts a part of it, ſo as to emit luminous flaſhes on being dropt into water. It is computed that one part of phoſphorus will communicate this property to 600,000 parts of ſpirit. The liquor is never obſerved to become luminous of itſelf, nor in any other circumſtance except that abovementioned. By digeſtion for ſome months, the undiſſolved phoſphorus is reduced to a tranſparent oil, which neither emits light nor concretes in the cold. By waſhing with water, it is in ſome meaſure revived; acquiring a thicker conſiſtence, and becoming again luminous, though in a leſs degree than at firſt. During this digeſtion, the glaſs is very apt to burſt.

1412 With eſſential oils and acids.

Phoſphorus is partially diſſolved by expreſſed oils; and totally, or almoſt ſo, in eſſential oils and ether. When eſſential oils are ſaturated with it by heat, a part of the phoſphorus ſeparates, on ſtanding in the cold, in a cryſtalline form. Concentrated ſpirit of ſalt has no action on it. In diſtillation, the ſpirit riſes firſt, and the phoſphorus after it unchanged. Spirit of nitre diſſolves it, and the diſſolution is attended with great heat and copious red fumes; ſo that great part of the ſpirit diſtils without the application of any external heat, and the phoſphorus at laſt takes fire, explodes, and burſts the veſſels. Oil of vitriol likewiſe diſſolves phoſphorus, but not without a heat ſufficient to make the acid diſtil. The diſtilled liquor is white, thick, and turbid; the reſiduum is a whitiſh tenacious maſs, which deliquates, but not totally, in the air. Phoſphorus itſelf is reſolved into an acid liquor on being expoſed two or three weeks to the air, its inflammable principle ſeeming by degrees to be diſſipated.

Phoſphorus has been reported to produce extraordinary effects in the reſolution of metallic bodies: but from the experiments that have been made with this view, it does not appear to have any remarkable action on them; at leaſt on the precious ones, gold and ſilver, for the reſolution or ſubtilization of which it has been chiefly recommended. The following experiments were made by Mr Margraaf.

1413 Mr Margraf's experiments with metals.

1. A ſcruple of filings of gold were digeſted with a drachm of phoſphorus for a month, and then committed to diſtillation. Part of the phoſphorus aroſe, and part remained above the gold, in appearance reſembling glaſs: this grew moiſt on the admiſſion of air, and diſſolved in water, leaving the gold unaltered. Half a drachm of fine ſilver, precipitated by copper, being digeſted with a drachm of phoſphorus for three hours, and the fire then increaſed to diſtillation, greateſt part of the phoſphorus aroſe pure, and the ſilver remained unchanged. Copper filings being treated in the ſame manner, and with the ſame quantity of phoſphorus, the phoſphorus ſublimed as before; but the remaining copper was found to have loſt its metallic brightneſs, and to take fire on the contact of flame. Iron filings ſuffered no change. Tin filings run into granules, which appeared to be perfect tin. Filings of lead did the ſame. The red calx of mercury, called *precipitat. per ſe*, treated in the ſame manner, was totally converted into running quickſilver. 2. Regulus of antimony ſuffered no change itſelf, but occaſioned a change in the conſiſtence of the phoſphorus; which, after being diſtilled from this ſemimetal, refuſed to congeal, and continued, under water, fluid like oil-olive. With biſmuth there was no alteration. A drachm of phoſphorus being diſtilled and cohobated with an equal quantity of zinc, greateſt part of the zinc ſublimed in form of very light pointed flowers of a reddiſh-yellow colour: theſe flowers, injected into a red hot crucible, took fire, and run into a glaſs reſembling that of borax. White arſenic, ſublimed with phoſphorus, aroſe along with it in form of a mixed red ſublimate. Sulphur readily unites with phoſphorus into a maſs which ſmells like *hepar ſulphuris*. This does not eaſily take fire on being rubbed; but expoſed to a moderate dry heat, it flames violently, and emits a ſtrong ſulphureous fume. If phoſphorus is burnt in an open veſſel, a quantity of acid remains behind; and if a glaſs bell is held over it, an acid likewiſe ſublimes in the form of white flowers.

1414 Mr Canton's phoſphorus.

3. *Mr Canton's phoſphorus*. This is a compoſition of quicklime and common ſulphur. The receipt for making it is as follows. "Calcine ſome common oyſter-ſhells, by keeping them in a good coal-fire for half an hour; let the pureſt part of the calx be pulverized and ſifted. Mix with three parts of this powder one part of flowers of ſulphur. Let this mixture be rammed into a crucible of about an inch and a half in depth till it be almoſt full; and let it be placed in the middle of the fire, where it muſt be kept red hot for an hour at leaſt, and then ſet by to cool: when cold, turn it out of the crucible; and cutting or breaking it to pieces, ſcrape off, upon trial, the brighteſt parts; which, if good phoſphorus, will be a white powder. This kind of phoſphorus ſhines on being expoſed to the light of the ſun, or on receiving an electrical ſtroke.

1415 Homberg's phoſphorus or pyrophorus.

4. *Phoſphorus of Homberg*. This ſubſtance, which has the ſingular property of kindling ſpontaneouſly when expoſed to the air, was accidentally diſcovered by Mr Homberg, as he was endeavouring to diſtil a clear flavourleſs oil from human excrements. Having mixed the excrement with alum, and diſtilled over as much as he could with a red heat, he was much ſurpriſed at ſeeing the matters left in the retort take fire upon being expoſed to the air, ſome days after the diſtillation was over. This induced him to repeat the operation, in which he met with the ſame ſucceſs; and he then publiſhed a proceſs, wherein he recommended alum and human excrement for the preparation of the phoſphorus. Since his time, however, the proceſs has been much improved; and it is diſcovered, that almoſt every vitriolic ſalt may be ſubſtituted for the alum, and moſt other inflammable ſubſtances for the excrement; but though alum is not abſolutely neceſſary for the ſucceſs, it is one of the vitriolic ſalts that ſucceed beſt. The following proceſs is recommended in the Chemical Dictionary.

1416 Beſt method of preparing.

Let three parts of alum and one of ſugar be mixed together. This mixture muſt be dried in an iron ſhovel, over a moderate fire, till it be almoſt reduced to a blackiſh powder or coal; during which time it muſt be ſtirred with an iron ſpatula. Any large maſſes muſt be

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be bruised into powder; and then it must be put into a glass matrass, the mouth of which is rather strait than wide, and seven or eight inches long. This matrass is to be placed in a crucible, or other earthen vessel, large enough to contain the belly of the matrass, with about a space equal to that of a finger all round it. This space is to be filled with sand, so that the matrass shall not touch the earthen vessel. The apparatus is then to be put into a furnace, and the whole to be made red hot. The fire must be applied gradually, that any oily or fuliginous matter may be expelled; after which, when the matrass is made red hot, fulphureous vapours exhale: this degree of heat is to be continued till a truly fulphureous flame, which appears at the end of the operation, has been seen nearly a quarter of an hour: the fire is then to be extinguished, and the matrass left to cool, without taking it out of the crucible; when it ceases to be red hot, it must be stopped with a cork. Before the matrass is perfectly cold, it must be taken out of the crucible, and the powder it contains poured as quickly as possible into a very dry glass phial, with a glass stopper. If we would preserve this phosphorus a long time, the bottle containing it must be opened as seldom as possible. Sometimes it kindles while it is pouring into the glass phial; but it may be then extinguished by closing the phial expeditiously. A small quantity of this pyrophorus laid on paper, and exposed to the air, immediately takes fire, becomes red like burning coals, and emits a strong fulphureous vapour greatly resembling that which arises on decomposing liver of sulphur.

1417 Is not injured by mere exposure to light.

It has been generally alleged, that the common black phosphorus is impaired by being exposed to the light; but Mr Cavallo has discovered the fallacy of this supposition by the following experiment. Some portions of the same pyrophorus were inclosed in three glass tubes, and immediately sealed up hermetically. On the 22th of May 1779, two of them were suspended from a nail out of a window, and the third was wrapped up in paper and inclosed in a box, where not the least glimmering of light could enter. In this situation they were left for more than a year; after which one of those that had been kept out of the window was broke, along with that which had been kept in the dark, in the presence of Mr Kirwan; when the pyrophorus seemed to be equally good in each tube, taking fire in about half a minute after it was taken out of the tubes, and exposed to the air on a piece of paper.

1418 Cause of the accension.

There are many different kinds of pyrophori: some of the most remarkable of which are described under the article PYROPHORUS. Many theories have been invented to solve the phenomenon of their accension on the contact of air. This has been thought owing to the conversion of the earth of alum into lime, or to a remainder of the vitriolic acid attracting moisture from the atmosphere; but the formation of pyrophorus without either alum or vitriolic acid, shows that neither of these opinions can be just. It is more probable, therefore, that, the heat is occasioned by the total dissipation of that aqueous part which is essential to the constitution of terrestrial substances. In consequence of this, the water contained in the atmosphere is not only attracted with avidity, but decompounded by the matter reduced to such a state of extreme dryness. By these operations it gives out the latent heat contained in it, and this produces the accension in question.

Oils.

§ 2. *Ardent Spirits.*

See FERMENTATION and DISTILLATION.

§ 3. *Oils.*

1. *Essential Oils.* Those oils are called *essential* which have evidently the smell of the vegetable from which they are drawn. For the method of procuring them, see DISTILLATION. They are distinguished from all others by their superior volatility, which is so great as to cause them rise with the heat of boiling water. All these have a strong aromatic smell, and an acrid, caustic taste; in which respect also they differ from other oils. This taste is thought to proceed from a copious and disengaged acid, with which they are all penetrated. The presence of this disengaged acid in essential oils, appears from the impression they make upon the corks of bottles in which they are kept. These corks are always stained of a yellow colour, and a little corroded, nearly as they are by nitrous acid. The vapour of these oils also reddens blue paper, and converts alkalies into neutral salts. 1419 Essential oils. 1420 Supposed cause of their taste.

This acid is likewise supposed to be the cause of their solubility in spirit of wine. They are not all equally soluble in this menstruum, because they do not all contain an equal quantity of acid. As this acid is much disengaged, they lose a great deal of it by repeated distillations, and therefore they become less and less soluble on being frequently distilled. By evaporation they lose their most volatile and thin part, in which the specific smell of the vegetable from which they are extracted resides; by which loss they become thick, and acquire the smell and consistence of turpentine, and even of resins. In this state they are no longer volatile with the heat of boiling water; and, if distilled with a stronger fire, they give over an oil which has neither smell nor taste of the vegetable whence they were extracted, but is entirely empyreumatic, and similar to those oils procured by distilling vegetable or animal substances with a strong fire. See DISTILLATION. 1421 Of their solubility in spirit of wine.

To the class of essential oils, the volatile concrete called *camphor* seems most properly to belong. With them it agrees in its properties of inflammability, solubility in spirit of wine, and a strong aromatic flavour. The only differences between them are, that camphor is always in a solid state, and is incapable of decomposition by any number of sublimations. 1422 Camphor.

It has, however, been found possible to decompose it by distillation with certain additions. By distilling it several times along with bole, we obtain a fluid having the properties of an essential oil, soluble in water, and separating again on the the addition of spirit of wine. On distilling it eight times with dephlogisticated nitrous acid, we obtain a salt having the form of a parallelopiped, of an acid and bitter taste, and changing the juice of violets and turnsole red. This has the properties of a true acid; combines with fixed and volatile alkalies into neutral salts capable of being crystallized; dissolves copper, iron, bismuth, arsenic, and cobalt. 1423 Decomposed by distillation with bole. 1424 With dephlogisticated nitrous acid.

Oils. cobalt. With magneſia it forms regular cryſtals, in ſome meaſure reſembling baſaltes. It is diſtinguiſhed from the acid of ſugar by not precipitating lime from its ſolution in marine acid, and by forming with magneſia a white powder ſoluble in water.

According to Neumann, all the camphor made uſe of is the produce of two ſpecies of trees; the one growing in Sumatra and Borneo, the other in Japan. Of theſe, the Japan kind is the only one brought into Europe. The tree is about the ſize of a large lime, the flowers white, and the fruit a ſmall red berry. All parts of the tree are impregnated with camphor; but the roots contain moſt, and therefore are chiefly made uſe of for the preparation of this commodity: though, in want of them, the wood and leaves are ſometimes mixed.

The camphor is extracted by diſtillation with water in large iron pots filled with earthen heads ſtuffed with ſtraw; greateſt part of the camphor concretes among the ſtraw, but paſſes down into the receiver among the water. In this ſtate it is found in ſmall bits like gray ſalt-petre, or common bay-ſalt; and requires to be purified either by a ſecond ſublimation, or by diſſolution in ſpirit of wine, filtration, and exſiccation. If the firſt method is followed, there will be ſome difficulty in giving it the form of a perfect tranſparent cake. A difficulty of this kind indeed always occurs in ſublimations; and the only way is to keep the upper part of the glaſs to ſuch a degree of heat as may keep the ſublimate in a half-melted ſtate. Dr Lewis recommends the depuration of camphor by ſpirit of wine, and then melting it into a cake in the bottom of a glaſs.

Camphor poſſeſſes conſiderable antiſeptic virtues; and is a good diaphoretic, without heating the conſtitution; with which intention it is often uſed in medicine. It is likewiſe employed in fire-works and ſeveral other arts, particularly in making varniſhes. See Varnish.

1425 Soluble in ardent ſpirits and oil. This ſubſtance diſſolves eaſily and plentifully in vinous ſpirits and in oils; four ounces of ſpirit of wine will diſſolve three of camphor. On diſtilling the mixture, the ſpirit riſes firſt, very little camphor coming over with it. This ſhows that camphor, however volatile it may ſeem by its ſmell, is very far from having the volatility of ether, and conſequently is improperly claſſed with ſubſtances of that kind.

1426 Empyreumatic oils. 2. *Empyreumatic Oils*. Under this name are comprehended all thoſe oils, from whatever ſubſtance obtained, which require a greater heat for their diſtillation than that of boiling water. Theſe are partially ſoluble in ſpirit of wine, and becomes more and more ſo by repeated diſtillations. The empyreumatic oils obtained from animal ſubſtances are at firſt more fetid than thoſe procured from vegetables; but by repeated diſtillations, they become exceedingly attenuated and volatile, becoming almoſt as white, thin, and volatile, as ether. They then acquire a property of acting upon the brain and nervous ſyſtem, and of allaying its irregular movements, which is common to them with all other inflammable matters when highly attenuated and very volatile, but this kind of oil is particularly recommended in epileptic and convulſive affections. It is given from 4 to 10 or 11 drops: but, though prepared with the utmoſt care, it is very ſuſceptible of loſing its whiteneſs, and even its thinneſs, by a ſhort expoſure to air; which proceeds from the almoſt inſtantaneous evaporation of its more thin and volatile parts, and from the property which the leſs volatile remainder has of acquiring colour. To avoid this inconvenience, it muſt be put, as ſoon as it is made, into very clean glaſs bottles with glaſs ſtoppers, and expoſed to the air as little as poſſible. Oils.

1427 How rectified. The moſt important obſervations concerning the method of making the pure animal oils are, firſt to change the veſſel at each diſtillation, or at leaſt to make them perfectly clean; for a very ſmall quantity of the thicker and leſs volatile part is ſufficient to ſpoil a large quantity of that which is more rectified. In the ſecond place, Mr Beaumé has obſerved, that this operation may be greatly abridged, by taking care to receive none but the moſt volatile part in each diſtillation, and to leave a large reſiduum, which is to be neglected, and only the more volatile part to be further rectified. By this method a conſiderable quantity of fine oil may be obtained at three or four diſtillations, which could not otherwiſe be obtained at fifty or ſixty.

1428 Animal fats. 3. *Animal Fats*. Though theſe differ conſiderably from one another in their external appearance, and probably in their medicinal qualities, they afford, on a chemical analyſis, products ſimilar in quality, and differing but inconſiderably in quantity. They all yield a larger portion of oil, and no volatile ſalt; in which reſpect they differ from all other animal ſubſtances. Two ounces of hogs's lard yielded, according to Neumann, two drachms of an empyreumatic liquor, and one ounce five drachms and 50 grains of a clear brown-coloured oil of a volatile ſmell, ſomewhat like horſe-radiſh. The *caput mortuum* was of a ſhining black colour, and weighed 10 grains.

1429 Tallow. Tallow being diſtilled in the ſame manner, two drachms of empyreumatic liquor were obtained from two ounces of it; of a clear brown oil, ſmelling like horſe-radiſh, one ounce ſix drachms and 12 grains. The remaining coal was of a ſhining black colour, and weighed 18 grains. A particular kind of acid is now found to be contained in it.

1430 Marrow. The marrow of bones differs a little from fats, when chemically examined. Four ounces of freſh marrow, diſtilled in the uſual manner, gave over three drachms and a ſcruple of a liquor which ſmelled like tallow; two ſcruples and an half of liquor which had more of an empyreumatic and a ſouriſh ſmell; two ounces and an half of a yellowiſh-brown, butyraceous oil, which ſmelled like horſe-radiſh; and ſix drachms and an half of a blackiſh-brown oil of the ſame ſmell. The *caput mortuum* weighed four ſcruples.

1431 Rancid oils purified. All animal fats, when perfectly pure, burn totally away without leaving any feces, and have no particular ſmell. In the ſtate in which we commonly find them, however, they are exceedingly apt to turn rancid, and emit a moſt diſagreeable and noxious ſmell; and to this they are peculiarly liable, when long kept in a gentle degree of heat. In this ſtate, too, an inflammable vapour ariſes from them, which when on fire is capable of producing exploſions. Hence, in thoſe works where large bellows are uſed, they have been often ſuddenly burſt by the inflammable vapours ariſing from the rancid oil employed for ſoftening the leather

Resins and Balsams.

leather. The expreſſed unctuous oils of vegetables are ſubject to the ſame changes; but from this rancidity they may all be freed moſt effectually, by the ſimple proceſs of agitating them well with water: which is to be drawn off, and freſh quantities added, till it comes off at laſt clear and inſipid, without any ill ſmell. The proper inſtrument for performing this operation in large is a barrel-churn, having in it four rows of narrow ſplit deals, from the centre to the circumference, each piece ſet at obtuſe angles to the other, in order to give different directions to the oil and water as the churn turns round, thereby to mix them more intimately. The churn is to be ſwiftly turned round for a few minutes; and muſt then be left at reſt, till the oil and water have fully ſeparated; which will be in 15 or 20 minutes, more or leſs, according to the ſize of the churn. When this water is drawn off, freſh water is to be put in, and the churn again turned round, and this continued till the oil is perfectly ſweet. If the oil and water are allowed to ſtand together for ſome days, a gelatinous ſubſtance is found between them, which is not very eaſily miſcible either with oil or water. Chalk, quicklime, and alkaline ſalts, are found alſo capable of taking off the rancidity from oils and fats; but have the inconvenience of deſtroying a part of their ſubſtance.

§ 4. *Resins and Balsams.*

These are commonly reckoned to be compoſed of an eſſential oil thickened by an acid; as the eſſential oils themſelves are found to be convertible into a ſimilar ſubſtance, by the exhalation of their more volatile parts. True reſins are generally tranſparent in a conſiderable degree, ſoluble in ſpirit of wine, and poſ-
1432 ſeſſed of a conſiderable degree of flavour.

Whence procured.

Reſins are originally produced by inſpiſſating the natural juices which flow from inciſions made in the ſtems of growing vegetables, and are in that ſtate called *balſams*. The balſams may be conſidered as eſſential oils thickened by loſing ſome of their odoriferous principle, and of their fineſt and moſt volatile parts. There are ſeveral kinds of balſams, which, however, differ from each other only in the ſmell and degree of conſiſtence; and therefore all yield ſimilar products on diſtillation. An analyſis of turpentine therefore will be ſufficient as an example of the analy-
1433 ſis and natural properties of all the reſt.

Turpentine Chio.

The true turpentine-tree is found in Spain and the ſouthern parts of France, as well as in the iſland of Chio and in the Indies. It is a middling-ſized evergreen-tree, with leaves like thoſe of the bay, bearing purpliſh, imperfect flowers; and on ſeparate pedicles hard unctuous berries like thoſe of juniper. It is extremely reſinous; and unleſs the reſin is diſcharged, decays, produces fungous excreſcences, ſwells, burſts, and dies; the prevention of which conſiſts wholly in plentiful bleeding, both in the trunk and branches. The juice is the *Chio* or *Cyprus turpentine* of the ſhops. This ſort is quite of a thick conſiſtence, of a greeniſh white colour, clear and tranſparent, and of ſcarcely
1434 any taſte or ſmell.

Venice.

The kind now called *Venice turpentine*, is no other than a mixture of eight parts of common yellow or black roſin with five parts of oil of turpentine. What was originally Venice turpentine is now unknown. Neumann relates, that the Venice turpentine ſold in his country was no other than that prepared from the larix tree, which grows plentifully in ſome parts of France, as alſo in Auſtria, Tyrol, Italy, Spain, &c. Of this there are two kinds; the young trees yielding a thin limpid juice, reſembling balſam of copaiba; the older, a yellower and thicker one. 1435

Straſburg.

The *Straſburg turpentine* is extracted from the ſilver-fir. Dr Lewis takes notice that ſome of the exotic firs afford balſams, or reſins, ſuperior to thoſe obtained from the native European ones; as particularly that called *balm of Gilead fir*, which is now naturalized to our own climate. A large quantity of an elegant reſinous juice may be collected from the cones of this tree: the leaves alſo, when rubbed, emit a fragrant ſmell; and yield, with rectified ſpirit, an agreeable reſinous extract. 1436

Common.

The common turpentine is prepared from different ſorts of the pine; and is quite thick, white, and opaque. Even this is often counterfeited by mixtures of roſin and common expreſſed oils. 1437

Phenomena on diſtillation.

All the turpentines yield a conſiderable proportion of eſſential oil. From ſixteen ounces of Venice turpentine, Neumann obtained, by diſtillation with water, four ounces and three drachms of oil. The ſame quantity diſtilled, without addition, in the heat of a water-bath, gave but two ounces and an half; and from the reſiduum treated with water, only an ounce could be obtained. The water remaining in the ſtill is found to have imbibed nothing from the turpentine; on the contrary, the turpentine is found to imbibe part of the water; the reſiduum and the oil amounting to a full ounce on the pound more than the turpentine employed. When turpentine is diſtilled or boiled with water till it becomes ſolid, it appears yellowiſh; when the proceſs is further continued, of a reddiſh brown colour: in the firſt ſtate, it is called *boiled turpentine*; and in the latter, *colophony*, or *roſin*.

On diſtilling ſixteen ounces of turpentine in a retort with an open fire, increaſed by degrees, we obtain firſt four ounces of a limpid colourleſs oil; then two ounces and two drachms of a yellowiſh one; four ounces and three drachms of a thicker yellow oil; and two ounces and one drachm of a dark browniſh red empyreumatic oil, of the conſiſtence of balſam, and commonly called *balſam of turpentine*. 1438

Eſſential oil difficult of ſolution.

The limpid eſſential oil called *ſpirit of turpentine*, is exceedingly difficult of ſolution in ſpirit of wine; tho' turpentine itſelf diſſolves with great eaſe. One part of the oil may indeed be diſſolved in ſeven parts of rectified ſpirit; but on ſtanding for ſome time, the greateſt part of the oil ſubſides to the bottom, a much greater proportion of ſpirit being requiſite to keep it diſſolved. 1439

Benzoin.

2. *Benzoin.* This is a very brittle browniſh reſin, of an exceedingly fragrant ſmell. The tree which produces benzoin is a native of the Eaſt Indies; particularly of Siam and the iſland of Sumatra. It is never permitted to exceed the ſixth year; being, after this time, unfit for producing the benzoin. It is then cut down, and its place ſupplied by a young tree raiſed commonly from the fruit. One tree does not yield above three pounds of benzoin.

A tree ſuppoſed to be the ſame with that which affords

Bitumens.

ford benzoin in the East Indies, is plentiful also in Virginia and Carolina; from whence it has been brought into England, where it grows with vigour in the open ground. The bark and the leaves have the smell of benzion; and yield with rectified spirit a resin of the same smell; but no resin has been observed to issue from it naturally in England, nor has any benzoin been collected from it in America.

1440 Soluble in spirit of wine.

Benzoin dissolves totally in spirit of wine into a blood-red liquor, leaving only the impurities, which commonly amount to no more than a scruple on an ounce. To water, it gives out a portion of saline matter of a peculiar kind, volatile and sublimable in the fire. See 984 *et seq.*

The principal use of resins is in the making of lacquers, varnishes, &c. See VARNISH.

§ 5. *Bitumens.*

THESE are inflammable mineral bodies, not sulphureous, or only casually impregnated with sulphur. They are of various degrees of consistency; and seem, in the mineral kingdom, to correspond with the oils and resins in the vegetable.

1441 Origin of bitumens.

Concerning the origin of bitumens, chemists are not at all agreed. Some chemical writers, particularly Mr Macquer, imagine bitumens to be no other than vegetable resins altered in a peculiar manner by the admixture of some of the mineral acids in the earth; but Dr Lewis is of a contrary opinion, for the following reasons.

"Mineral bitumens are very different in their qualities from vegetable resins; and, in the mineral kingdom, we find a fluid oil very different from vegetable oils. The mineral oil is changed by mineral acids into a substance greatly resembling bitumens; and the vegetable oils are changed by the same acids into substances greatly resembling the natural resins.

"From bitumens we obtain, by distillation, the mineral oil, and from resins the vegetable oil, distinct in their qualities as at first. Vegetable oils and resins have been treated with all the known mineral acids; but have never yielded any thing similar to the mineral bitumens. It seems, therefore, as if the oily products of the two kingdoms were essentially and specifically different. The laws of chemical inquiries at least demand, that we do not look upon them any otherwise, till we are able to produce from one a substance similar to the other. When this shall be done, and not before, the presumption that nature effects the same changes in the bowels of the earth, will be of some weight."

1442 Naphtha.

There is a perfectly fluid, thin bitumen, or mineral oil, called *naphtha*, clear and colourless as crystal; of a strong smell; extremely subtile; so light as to swim on all known liquors, ether perhaps excepted: spreading to a vast surface on water, and exhibiting rainbow colours; highly inflammable: formerly made use of in the composition of the supposed inextinguishable greek fire.

1443 Petroleum.

Next to this in consistence is the *oleum petra*, or *petroleum*; which is grosser and thicker than naphtha, of a yellowish, reddish, or brownish colour; but very light, so as to swim even on spirit of wine. By distillation, the petroleum becomes thinner and more subtile, a gross matter being left behind; it does not, however, easily arise, nor does it totally lose its colour by this process, without particular managements or additions.

Both naphtha and petroleum are found plentifully in some parts of Persia, trickling through rocks or swimming on the surface of waters. Kempfer gives an account of two springs near Baku; one affording naphtha, which it receives in drops from subterraneous veins; the other, a blackish and more fetid petroleum, which comes from Mount Caucasus. The naphtha is collected for making varnishes; the petroleum is collected in pits, and sent to different places for lamps and torches.

Native petrolea are likewise found in many different places, but are not to be had in the shops; what is sold there for petroleum, being generally oil of turpentine coloured with alkanet root. The true naphtha is recommended against disorders of the nerves, pains, cramps, and contractions of the limbs, &c. but genuine naphtha is rarely or never brought to this country.

There are some bitumens, such as amber, ambergris, pit-coal, and jet, perfectly solid; others, such as Barbadoes tar, of a middle consistence between fluid and solid. Turf and peat are likewise thought to belong to this class.

1. *Amber.* This substance melts, and burns in the fire, emitting a strong peculiar smell. Distilled in a strong heat, it yields a phlegm, an oil, and a particular species of acid salt. The distillation is performed in earthen or glass retorts, frequently with the addition of sand, sea-salt, coals, &c. which may break the tenacity of the melted mass, so as to keep it from swelling up, which it is apt to do by itself. These additions, however, make a perceptible difference in the produce of the distillation: with some the salt proves yellowish and dry; with others, brownish or blackish, and unctuous or soft like an extract: with some, the oil is throughout of a dark brown colour; with others, it proves externally green or greenish; with elixated ashes, in particular, it is of a fine green. The quantity of oil and phlegm is greatest when coals are used, and that of salt when sea-salt is used. 1444 Amber.

The most advantageous method of distilling amber, however, is without any addition; and this is the method used in Prussia, where the greatest quantities of salt and oil of amber are made. At first a phlegmatic liquor distils; then a fluid oil; afterwards one that is thick and more ponderous; and last of all, an oil still more ponderous along with the salt. In order to collect the salt more perfectly, the receiver is frequently changed; and the phlegm, and light oil, which arise at first, are kept by themselves. The salt is purified, by being kept some time on bibulous paper, which absorbs a part of the oil: and changing the paper as long as it receives any oily stain. For the further depuration as well as the nature of this salt, see SUCCINUM. 1445 Most advantageously distilled without addition.

2, *Ambergris.* This concrete, which is only used as a perfume, yields, on distillation, products of a similar nature to that of amber, excepting that the volatile salt is in much less quantity. See AMBERGRIS. 1446 Ambergris.

3. *Pit-coal.* See the articles COAL and LITHANTHRAX 1447 Pit-coal.

Bitumens. THRAX. This ſubſtance yields by diſtillation, according to the tranſlator of the Chemical Dictionary, 1. phlegm, or water; 2. a very acid liquor; 3. a thin oil, like naphtha; 4. a thicker oil, reſembling petroleum, which falls to the bottom of the former, and which riſes with a violent fire; 5. an acid, concrete ſalt; 6. *an uninflammable earth* (we ſuppoſe he means a piece of charred coal, or cinder) remains in the retort. The fluid oil obtained from coals is ſaid to be exceedingly inflammable, ſo as to burn upon the ſurface of water like naphtha itſelf.

1448 Peat. 4. *Peat.* There are very conſiderable differences in this ſubſtance, proceeding probably from the admixture of different minerals: for the ſubſtance of peat is plainly of vegetable origin; whence it is found to anſwer for the ſmelting of ores, and the reduction of metallic calces, nearly in the ſame manner as coals of wood. Some ſorts yield, in burning, a very diſagreeable ſmell, which extends to a great diſtance; whilſt others are inoffenſive. Some burn into grey or white, and others into red, ferruginous aſhes. The aſhes yield, on elixation, a ſmall quantity of alkaline, and ſome neutral ſalts.

1449 Phenomena on diſtillation. The ſmoke of peat does not preſerve or harden fleſh like that of wood; and the ſoot into which it condenſes is more apt to liquefy in moiſt weather. On diſtilling peat in cloſe veſſels, there ariſes a clear inſipid phlegm; an acid liquor, which is ſucceeded by an alkaline one; and a dark-coloured oil. The oil has a very pungent taſte, and an empyreumatic ſmell; leſs fetid than that of animal ſubſtances, but more ſo than that of mineral bitumens. It congeals, in the cold, into a pitchy maſs, which liquefies in a ſmall heat: it readily catches fire from a candle; but burns leſs vehemently than other oils, and immediately goes out upon removing the external flame. It diſſolves almoſt totally in rectified ſpirit of wine, into a dark, browniſh-red liquor.

§ 6. CHARCOAL.

1450 Differences between the coals of different ſubſtances. THIS is the form to which all inflammable matters are reducible, by being ſubjected to the moſt vehement action of fire in cloſe veſſels; but though all the coals are nearly ſimilar to one another in appearance, there is nevertheleſs a very conſiderable difference among them as to their qualities. Thus the charcoal of vegetables parts with its phlogiſton very readily, and is eaſily reducible to white aſhes: charred pit-coal, or, as it is commonly called, *coak*, much more difficultly; and the coals of burnt animal ſubſtances, far more difficultly than either of the two. Mr Macquer acquaints us, that the coal of bullock's blood parts with its phlogiſton with the utmoſt difficulty. He kept it very red, in a ſhallow crucible ſurrounded with charcoal, for ſix hours and more, ſtirring it conſtantly that it might be all expoſed to the air, without being able to reduce it to white, or even grey aſhes. It ſtill remained very black, and full of phlogiſton. The coals of pure oils, or concrete oily ſubſtances, and ſoot, which is a kind of coal raiſed during the inflammation of oils, are as difficultly burnt as animal coals. Theſe coals contain very little ſaline matter, and their aſhes furniſh no alkali. Theſe coals, which are ſo difficultly burnt, are alſo leſs capable of inflaming with nitre than others more combuſtible; and ſome of them, in a great meaſure, reſiſt even the action of nitre itſelf.

1451 Charcoal perfectly refractory. Charcoal is the moſt refractory ſubſtance in nature; no inſtance having been known of its ever being melted, or ſhowing the leaſt diſpoſition to fuſion, either by itſelf, or with additions: hence, charcoal is found to be the moſt proper ſupport for ſuch bodies as are to be expoſed to the focus of a large burning glaſs. The only true ſolvent of charcoal is *hepar ſulphuris*. By the violent heat of a burning-glaſs, however, it is found to be entirely diſſipable into inflammable air, without having any reſiduum. See AEROLOGY, n° 129. and CHARCOAL.

The different ſubſtances mixed with different coals, render ſome kinds of charcoal much leſs fit to be uſed in reviving metals from their calces, or in ſmelting them originally from their ores. The coals of vegetable ſubſtances are found to anſwer beſt for this purpoſe. See METALLURGY.

SECT. V. *Vegetable and Animal Subſtances.*

Vegetable and animal ſubſtances.

THE only ſubſtances afforded by vegetables or animals, which we have not yet examined, are the mucilaginous, or gummy; and the colouring parts obtained by infuſion, or boiling in water; and the calculous concretions found in the bodies of animals, chiefly in the human bladder. The colouring matter is treated of under the article *Colour-Making*, to which we refer; and in this ſection ſhall only conſider the nature of the others.

§ 1. MUCILAGE or GUM.

THE mucilage of vegetables is a clear tranſparent ſubſtance, which has little or no taſte or ſmell, the conſiſtence of which is thick, ropy, and tenacious, when united with a certain quantity of ſuperabundant water. It is entirely and intimately ſoluble in water, and contains no diſengaged acid or alkali. 1452 Mucilage.

When mucilage is diſſolved in a large quantity of water, it does not ſenſibly alter the conſiſtence of the liquor: but, by evaporation, the water grows more and more thick; and, at laſt, the matter acquires the conſiſtence of gum arabic, or glue; and this without loſing its tranſparency, provided a heat not exceeding that of boiling water has been uſed.

Gums, and ſolid mucilages, when well dried and very hard, are not liquefied in the fire like reſins, but ſwell, and emit many fumes; which are, at firſt, watery: then oily, fuliginous, and acrid. Diſtilled in cloſe veſſels, an aqueous acid liquor comes over along with an empyreumatic oil, as from other vegetable ſubſtances; a conſiderable quantity of coal remains, which burns to aſhes with difficulty. 1453 Phenomena on diſtillation.

Mucilages and gums are not ſoluble either by oils, ſpirit of wine, alkalies, or acids, except in ſo far as they diſſolve in theſe liquors by means of the water in which the alkali or acid are diſſolved. They are, however, the moſt effectual means of uniting oil with water. Three parts of mucilage, poured upon one part of oil, will incorporate with it by trituration or agitation; and the compound will be ſoluble in water. Vegetable gums are uſed in medicine, as well as the mechanic arts; but the particular uſes to which each of them is applicable, will be mentioned under the name of each particular gum.

Calculus.

1454 Jelly and Glue.

The mucilage obtained from animal ſubſtances, when not too thick, is called *jelly*, or *gelatinous matter*; when further inſpiſſated, the matter becomes quite ſolid in the cold, and is called *glue*. If the evaporation is ſtill further continued, the matter acquires the conſiſtence of horn.

This gelatinous ſubſtance ſeems to be the only true animal one; for all parts of the body, by long continued boiling, are reducible to a jelly, the hardeſt bones not excepted. Animal jelly, as well as vegetable mucilage, is almoſt inſipid and inodorous; but, though it is difficult to deſcribe the difference betwixt them when apart, it is very eaſily perceived when they are both together. Acids and alkalies, particularly the latter, diſſolve animal jellies with great eaſe; but the nature of theſe combinations is not yet underſtood. The other properties of this ſubſtance are common to it with the vegetable gums, except only that the animal mucilage forms a much ſtronger cement than any vegetable gum: and is therefore much employed for mechanical purpoſes, under the name of *glue*. See Glue and Isinglass.

§ 2. *Of the* Human Calculus.

1455 Scheele's experiments on the human calculus.

This ſubſtance has been repeatedly examined by the moſt eminent chemiſts. Mr Scheele, as has been related n° 982, *et ſeq.* has been able to extract an acid from it. His account of it in other reſpects is to the following purpoſe.

1. All the calculi examined, whether flat and poliſhed, or rough and angular, were of the ſame nature, and conſiſted of the ſame conſtituent parts.

2. The diluted vitriolic acid has no effect upon the calculus, but the concentrated acid diſſolves it, and by abſtraction from it is converted into the ſulphureous kind, leaving a black coal behind.

3. Neither diluted nor concentrated ſpirit of ſalt had any effect upon it.

4. By means of nitrous acid, a new one was produced, and which is poſſeſſed of ſingular qualities, as already mentioned.

5. The ſolution of calculus in nitrous acid is not precipitated by ponderous earth, nor are metallic ſolutions ſenſibly altered by it.

6. It is not precipitated by alkalies, but grows ſomewhat yellower by a ſuperabundance of the latter. In a ſtrong digeſting heat the liquor becomes red, and tinges the ſkin of the ſame colour. It precipitates green vitriol of a black colour; vitriol of copper, green; ſilver, grey; corroſive ſublimate, zinc, and lead, white.

7. The ſolution is decompoſed by lime-water, and lets fall a white precipitate, ſoluble in the muriatic acid without any efferveſcence: but though there be an exceſs of precipitate, the liquor ſtill remains acid; which happens alſo with animal earth, and that of fluor diſſolved in the ſame acids. On evaporation to dryneſs, the matter will at laſt take fire; but when heated only to a dull red heat in a cloſe crucible, it grows black, ſmells like burnt alum, and efferveſces with acids; being convertible before the blow-pipe into quicklime.

8. Neither this ſolution, nor the alkaline mixture, is changed by the acid of ſugar.

9. The calculus is not changed by acid of tartar, though it is diſſolved even in the cold by alkali, when reduced to ſuch a ſtate of cauſticity as not to diſcover the leaſt mark of aerial acid. The ſolution is yellow and taſtes ſweetiſh; and is precipitated by all the acids, even by the aerial. It decompoſes metallic ſolutions, but does not precipitate lime-water; and a ſmell of volatile alkali is produced by a little ſuperabundance of alkali in the ſolution. Dry volatile alkali has no effect upon the calculus; but cauſtic volatile alkali diſſolves it, though a pretty large quantity is required for this purpoſe.

10. Calculus is likewiſe diſſolved by digeſting in lime-water; and for this purpoſe four ounces of lime-water are required to twelve grains of the calculus; but the latter is partly precipitated by adding acids to the ſolution. By this union the lime-water loſes its cauſtic taſte.

11. Calculus is alſo diſſolved entirely by pure water; but for this purpoſe a large quantity of fluid is required. Eight grains of calculus in fine powder will diſſolve by boiling for a ſhort time in five ounces of water. The ſolution reddens tincture of lacmus, but does not precipitate lime-water; and when it grows cold, the greateſt part of the calculus ſeparates in fine cryſtals.

12. On diſtilling a drachm of calculus in a glaſs retort, a volatile liquor was obtained reſembling hartſhorn, but without any oil; and in the neck of the veſſel was a brown ſublimate. On heating the retort thoroughly red hot, and then leaving it to cool, a black coal was left, weighing 12 grains, which retained its black colour on a red hot iron in the open air. The ſublimate, which had ſome marks of fuſion, weighed 28 grains, and became white by a new ſublimation. Its taſte was ſomewhat ſouriſh, but it had no ſmell; it was ſoluble both in water and in ſpirit of wine; but a larger quantity of ſpirit than of water was requiſite for this purpoſe. It did not precipitate lime-water, and ſeemed in ſome reſpects to agree with the ſal ſuccini.

1456 His concluſions concerning its compoſition.

From theſe experiments our author concludes, that the human calculus is neither calcareous nor gypſeous; but conſiſts of an oily, dry, volatile acid, united with ſome gelatinous matter. The calculus is an oily ſalt, in which the acid prevails a little, ſince it is ſoluble in pure water; and this ſolution reddens the tincture of lacmus. That it contains phlogiſton, appears from its ſolution in cauſtic alkalies and lime-water, but eſpecially from the effect of the nitrous acid, by which it acquires quite different properties than from ſolution in alkalies; nor can it be precipitated from this ſolution. The animal gelatinous ſubſtance appears on diſtillation, by which a liquor is obtained reſembling ſpirit of hartſhorn, and a fine coal is left behind.

1457 Is found univerſally in urine.

13. Calculus is found diſſolved in all urine, even in that of children. On evaporating four kannes of freſh urine to two ounces, a fine powder is depoſited as it cools, and a part firmly adheres to the glaſs. The precipitated powder readily diſſolves in a few drops of cauſtic fixed alkali; and has in other reſpects all the properties of calculus. Of the ſame nature is the lateritious ſediment depoſited by the urine of thoſe who labour under an ague. Mr Scheele ſuſpected at firſt, that there was in this urine ſome unknown menſtruum which kept ſuch a quantity of powder diſſolved, and which might afterwards evaporate by expoſure to the air; but altered his opinion on perceiving that the ſediment was equally depoſited in cloſe veſſels.

14. All urine contains ſome animal earth combined with phoſphoric acid; by the ſuperabundance of which acid,

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1458 Why fresh urine reddens lacmus.

acid, the earth is kept dissolved; and by reason of this superabundant acid fresh urine communicates a red colour to lacmus. By saturation with caustic volatile alkali a white powder is precipitated; of which three drachms and an half are obtained from four kannes of urine. It is soluble in nitrous acid; and on adding the vitriolic, some gypsum is precipitated. On evaporating the nitrous acid, another remained, which precipitated lime-water; and when mixed with lamp-black, afforded phosphorus by distillation; whence it is evident, that the white powder just mentioned contained lime and phosphoric acid.

1459 Salts, &c. contained in urine.

15. From these experiments Mr Scheele concludes, that all urine contains, besides the substances already known (*viz.* sal ammoniac, common salt, digestive salt, Glauber's salt, microcosmic salt, sal perlatum, and an oily extractive matter), a concrete acid, or that of calculus, and animal earth. It is also remarkable, that the urine of the sick is more acid, and contains more animal earth than that of healthy persons. With regard to the sal perlatum, it was afterwards discovered by Mr Scheele not to be a peculiar acid, but only a phosphoric acid disguised by a small quantity of fossil alkali united with it. The analysis is confirmed by synthesis; for, by combining fossil alkali with phosphoric acid, our author obtained a true perlate acid.

1460 Bergman's account of the calculus.

In a supplement to Mr Scheele's dissertation on the calculus, Mr Bergman observes, that he could not succeed in dissolving it entirely either in pure water or in the nitrous acid, though the undissolved part was the less in proportion to the fineness of the powder to which the calculus was reduced. The undissolved part appears most conspicuous, when small pieces, or small calculi of a few grains weight only, are put into a superabundant quantity of menstruum, and kept in a degree of heat very near to that which makes water boil. Here it will be observed, that the greatest part of the piece is dissolved; but that at the same time some small white spongy particles remain, which are not affected either by water, spirit of wine, acids, or caustic volatile alkali. If the liquor be made fully to boil, these particles divide into white rare flocculi, and become almost imperceptible, but without any entire dissolution. Mr Bergman could not collect a sufficient quantity of them to determine their nature with accuracy; only he observed, that when exposed to a strong heat, they were reduced to a coal which burns slowly to ashes, and is not soluble in diluted nitrous acid.

"When calculus vesicae (says he) is dissolved in nitrous acid, no precipitation ensues on adding the acid of sugar; whence one is readily induced to conclude, that there is no calcareous earth present, because this experiment is the surest way to discover it. But I have found, in the variety of experiments concerning elective attractions, that the addition of a third substance, instead of disuniting two already united, often unites both very closely. That the same thing happens here I had the more reason to believe, because the acid of sugar contains some phlogistic matter, though of such a subtle nature, that, on being burned, it does not produce any sensible coal; and the event of my experiment has shown, that I was not mistaken in my conjecture. In order to ascertain this point, I burned coals of the calculus to ashes, which were quite white, and showed in every respect the same phenomena as lime; caused some effervescence during their solution in acids, united with vitriolic acid into gypsum, were precipitated by the acid of sugar, and were partly soluble in pure water, &c. Notwithstanding this, there remains about one-hundredth part of the ashes insoluble in aquafortis; being the remainder of the substance abovementioned, which, together with the concrete acid, constitutes the calculus. If the calculus be dissolved in nitrous acid, the solution filtered and evaporated to dryness, and the dry mass calcined to whiteness, a calcareous powder is thus likewise obtained."

1461 Calcareous earth separated from it by vitriolic acid.

As pure vitriolic acid contains no phlogiston, our author supposed, that by dropping it, in its concentrated state, into a solution of calculus in nitrous acid, the calcareous earth, if any existed in it, would be discovered. In this he was not disappointed; for when the solution was saturated, some small crystals were thus immediately separated. These, on examination, were found to be gypsum; and, after being dissolved in distilled water, were precipitated by acid of sugar. When the solution of calculus was very much diluted, no change appeared at first on the addition of oil of vitriol; but after a little evaporation, the abovementioned crystals began to appear. Some calculi of the bladder or kidneys at least certainly contain lime, but seldom more than one half in an hundred parts, or one in 200 parts.

By the assistance of heat, concentrated vitriolic acid dissolves the calculus with effervescence, and the solution is of a dark brown colour. On adding a little water, a kind of coagulation takes place; but by adding more, the liquor again becomes clear, and assumes a yellowish colour. Mr Bergman agrees with Mr Scheele in supposing that the muriatic acid has no effect upon the calculus; but he is in no doubt whether it may not extract some part of the calcareous earth.

1462 Red colour of the nitrous solution accounted for.

The red colour assumed by the solution of calculus in aquafortis is remarkable. A saturated solution discovers no smell of nitrous acid, and if evaporated by itself in a large open vessel, the liquor assumes at last a deep red colour, and scarcely contains any nitrous acid: for, on the one hand, paper tinged with lacmus scarce shows any redness; and, on the other, the colour is destroyed irrecoverably by the addition of any acid. By quick evaporation the solution at last swells into innumerable bubbles; the foam grows redder and redder, and at last becomes dark red after it is quite dry. This dry mass communicates its colour to a much larger quantity of water than before, and dissolves very readily in all acids, even such as have no action on the calculus; but they entirely destroy the colour, and that the more quickly in proportion to their degree of strength; even alum has this effect on account of the small quantity of loose acid it contains. Caustic alkalies also dissolve the colouring matter, and destroy it, but more slowly.

Our author endeavours to account for this red colour produced by the nitrous acid, from the peculiar nature of that acid and the effect it has upon phlogiston. In order to obtain it, a proportionable quantity of acid must be made use of, and it ought to be diluted, that there may be no danger of going beyond the necessary limit. If too much be used, it will not produce the proper effect; but, by reason of its superabundance, more or less, or even the whole, will be destroyed in proportion to the quantity. By pouring it in an undiluted state on powdered calculus, it is

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converted in a few moments into mere foam. The acid of calculus is the more easily separated from the aquafortis by evaporation, as the latter is rendered more volatile by the inflammable particles of the former: alkali added to them both united does not produce any precipitation; a circumstance generally observed where two acids are united. In this case both the acids unite with the alkali, according to the different laws of their attraction. The red mass obtained after deficcation is, however, very different from the concentrated acid, such as is contained in the calculus; for it is of a darker colour, and very deliquescent: the least particle gives a rose colour to a very considerable quantity of water; but the muriatic and other strong acids always certainly destroy it; and, in a longer or shorter time, produce a colourless solution. This remarkable change depends, according to our author, more on the action of the nitrous acid upon the inflammable part, than upon any thing remaining behind.—Such red spots as are produced upon the skin by the solution, are likewise produced upon bones, glass, paper, and other substances; but more time is required for their becoming visible, though this too may be a little accelerated by means of heat.

1463 Experiments of Mr Higgins on this subject.

The following is an abstract of Mr Higgins's experiments upon this subject.

1. Eight hundred and forty grains of dry and well powdered calculus were introduced into a glass retort. It was taken from a laminated stone with a small nucleus, which was likewise laminated. The outward crust appeared very porous, but increased in density towards the centre. By the application of heat, an elastic fluid was first slowly extricated; and which, on examination, appeared to be composed of equal parts of fixed and phlogisticated air. The last portions came over very fast, and were attended with an urinous smell; and, by continuing the distillation, it became evident that fixed and alkaline air came over together without forming any union, as they ought, on the common principles of chemistry, to have done; though our author is at a loss to know why they did not unite, unless they were prevented by the small quantity of inflammable air which came over along with them.

From the beginning of the 10th measure, a black, charry, and greasy matter began to line the conical tube and air-vessel adapted to the retort; and as the process went on, the proportion of alkaline air decreased, while that of the inflammable air was augmented, until towards the end, when the last nine measures were all inflammable; after which no more would come over, though the retort was urged with a white heat. On breaking the distilling vessel, a black powder weghing 95 grains was found in it. On digesting this for an hour in ten ounces of distilled water, and then filtering and evaporating it to two ounces, a yellowish powder was precipitated, but no crystals were formed after standing a whole night. This powder was then separated by filtration, and the liquor evaporated to one ounce; during which time more powder was precipitated. It was then filtered a second time, and the liquor evaporated to half an ounce; when it began to deposit a white powder, and to emit a subacid astringent vapour, not unlike that of vitriolic acid. This white precipitate, when washed and dried, amounted only to one grain, had a shining appearance, and felt very soft, not unlike mica in powder. It was not changed, but rather looked whiter by exposing it to a fierce heat for ten minutes. It dissolved in distilled water without being precipitated by caustic volatile alkali. Mineral alkali, acid of sugar, and nitrated terra ponderosa, rendered the solution turbid; whence our author inferred, that the powder in question was selenite.

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After the separation of this powder, the remaining solution was evaporated to dryness with a gentle heat. During the evaporation it continued to emit subacid vapours, leaving eleven grains of powder of a dirty yellow colour, having an aluminous taste. To this powder he added as much distilled water as was nearly sufficient to dissolve it; after which it was set by for three weeks. At the expiration of this term several small, transparent, and cubical crystals appeared on the side of the vessel above the surface of the solution; and these likewise had an aluminous taste. The whole was then dissolved in distilled water, and the solution filtered. Acid of sugar produced no change in the liquor for at least five minutes, but an immediate cloudiness took place on a mixture with volatile alkali; and on filtering the liquor it was again rendered turbid by mineral alkali, though the caustic alkali already predominated. Nitrated terra ponderosa threw down a copious precipitate, and Prussian alkali discovered a small quantity of iron. This aluminous solution left a yellow substance on the filter; which, when collected and dried, weighed only half a grain: it dissolved without effervescence in nitrous acid; acid of sugar caused no precipitation, but caustic volatile alkali threw down a precipitate which dissolved in distilled water. This solution was rendered turbid by the acid of sugar and muriated terra ponderosa, but no effect was produced by caustic volatile alkali or lime-water.

The yellow powder first deposited by the solution weighed two grains and a half, and by exposure to a strong heat acquired a deep orange colour. On digestion with distilled water, the insoluble part was reduced to three-fourths of a grain, and appeared to be iron: while the soluble part was found to be nothing else but gypsum. Our author, however, is of opinion, that this iron is impregnated with a small portion of vitriolic acid, though not in such quantity as to render it soluble.

The charred matter remaining in the retort was reduced by lixiviation with water to 80 grains. These were calcined with a red heat in an open fire, but could not be reduced to a grey powder in less than three quarters of an hour. When thoroughly calcined and cold, it weighed only 21 grains, which communicated to hot distilled water a limy taste, and gave it the property of turning syrup of violets green. Diluted vitriolic acid had no effect upon it, but it was rendered turbid by aerated volatile alkali and acid of sugar. The remainder when well dried weighed 16 grains, which dissolved in nitrous acid at first with a little effervescence; and when this ceased, the solution went on very slowly, until the whole was taken up. Acid of sugar made no change in the liquid, but the whole was precipitated by caustic volatile alkali. Prussian alkali threw down a grain, or perhaps more, of blue;

Calculus. blue; the precipitate digested with distilled vinegar lost a grain and an half, which was thrown down by caustic volatile alkali. The insoluble part being washed and digested in distilled water for half an hour, was partly dissolved; the solution was not affected by caustic volatile alkali, but acid of sugar and nitrated terra ponderosa caused an immediate cloudiness. Seven grains and an half of the powder, which was insoluble both in acetous acid and distilled water, were readily taken up by diluted vitriolic acid, and precipitated by caustic volatile alkali: the 16 grains last treated, therefore, appeared to contain, of clay $7\frac{1}{2}$ grains; of selenite, six grains; magnesia, one and a half; and of iron, one grain. The proportions of the different ingredients in the whole calculus, therefore, according to Mr Higgins, are as follows:

1464 His account of its component parts.

	Grains.
Iron	$2\frac{1}{9}$
Selenite	11
Clay	$7\frac{1}{2}$
Alum	8
Pure calcareous earth	5
Aerated magnesia	$1\frac{1}{2}$
Charry combustible substance	59
In all	$94\frac{1}{9}$

1465 Experiments on the sublimate arising from it on distillation.

In this experiment, a darkish yellow sublimate adhered to the neck of the retort; the inner part next the retort more compact, but the rest of a lamellar spongy texture. This sublimate, when carefully collected, was found to weigh 425 grains, and readily dissolved in eight ounces of hot distilled water. A coaly substance was separated from this solution by filtration, which, when washed and dried, weighed ten grains, and when exposed to a red heat burned with a greenish flame, emitting white fumes, which smelled like vitriolic sal ammoniac: the residuum after calcination weighed half a grain, and was of a whitish colour: appearing insoluble in distilled water, but dissolving with effervescence in nitrous acid. Acid of sugar caused a very small precipitation, which did not take place until the mixture had stood for some time; but caustic volatile alkali instantly threw down a precipitate, which was taken up, when washed, by the acetous acid. The quantity was too small to be examined with greater accuracy; but it seemed to possess the properties of magnesia. The saline solution had the colour of small beer; and, when evaporated to two ounces, did not deposit any sediment, or yield any crystals. The black matter with which the conical tube and air vessel were lined, weighed 28 grains, and adhered so fast to the glass, that it was impossible to collect the whole from the fragments of the glass. When dissolved in distilled water and filtered, four grains of coals, similar to that obtained from the former, were procured; but no signs of crystallization were observed after evaporation to one ounce, and suffering the liquor to stand all night.

By this treatment the solution acquired the consistence of treacle; so that it was plainly not crystallizable, and therefore its analysis was plainly to be attempted after a different method. It was now put into a tubulated glass retort, together with six ounces of distilled water to wash it down. By distillation in a sand-bath three ounces of water were procured, which differed in nothing from common distilled water, but in being coloured with a small quantity of the solution from the neck of the retort. On changing the receiver, about half an ounce of liquor of the same kind came over, after which the distillation began to be attended with an urinous smell. This continued barely perceptible for some time; but when about an ounce and an half had passed over, it became so very pungent, that our author could no longer doubt of its being in a caustic state. A small quantity of mild alkali, however, adhered to the lower part of the neck of the retort, some of which was washed down by the distillation; so that the proportions betwixt the two could not be ascertained. The volatile alkaline solution in the retort had the colour of spirit of hartshorn, and like it became darker coloured by the contact of air; on account of the evaporation of part of the alkali, and the rest becoming less capable of suspending the coaly matter mixed with it. Calculus.

After all the liquor had passed over, and nothing remained in the retort but a small quantity of black matter, the fire was raised; and, as the heat increased, this black substance acquired a white colour, with a kind of arrangement on the surface, which was occasioned by the heat applied to the bottom of the retort being only sufficient to raise the salt to the top of the matter in the retort; but as the sand became nearly red-hot, white fumes began to appear, which condensed on the upper part of the retort, and a little way down the neck. The process lasted until the matter was nearly red-hot, when the fumes ceased, and nothing more passed over. The sublimate, when collected, was found to weigh 72 grains, a black porous brittle substance remaining on the bottom of the retort, which weighed 12 grains. This residuum, when exposed to a strong heat, emitted white fumes, with a slight alkaline smell; by which process it was reduced, with very little appearance of combustion, to a grey powder weighing three grains, which was accidentally lost.

Five grains of this purified sublimate, mixed with as much quicklime, emitted no smell of volatile alkali; and, when thrown upon a red-hot iron, emitted white fumes. The same effect was produced by a mixture of equal quantities of vegetable alkali and sublimate. The remainder, consisting of 62 grains, was divided into two equal parts; the one of which was mixed with two ounces of distilled water, and on the other was poured 60 grains of vitriolic acid diluted with half an ounce of water. These two mixtures being suffered to remain for six weeks, seemed to be but little acted upon. That with vitriolic acid was then put into a small matrass, and boiled on sand for half an hour with two ounces of distilled water, when the whole was taken up. The solution looked clear, and deposited nothing on standing. Mild mineral alkali had no effect upon it; but mild vegetable alkali threw down a copious sediment in white flocculi, which was redissolved by caustic alkali, lime-water, and partly by mild mineral alkali. Phlogisticated alkali, acid of sugar, and acid of tartar, had no effect upon it. The other portion of sublimate, which had been mixed with distilled water, was very little dissolved; but in pouring it into a matrass some small round lumps were observable on the bottom of the glass. These were

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Calculus. six or seven in number, some weighing a whole grain, others not more than one-half. They were very hard and compact, with a smooth surface, and in figure resembling the nucleus of the original calculus. The whole was then put into a matrass with about three ounces of water. On boiling it on sand for three quarters of an hour, about one-half, of it was taken up: the solution passed the filter very clear whilst hot; but on cooling became turbid, and at last deposited white flocculi, which were redissolved on the addition of caustic volatile alkali and lime-water. It turned syrup of violets green; which, however, our author thinks might have been occasioned by its remaining volatile alkali, though it had not the smallest appearance of any such impregnation. He has nevertheless frequently observed, that sometimes the purest vegetable alkali contains volatile alkali, notwithstanding the various operations and degrees of heat it undergoes before it can be brought to the degree of purity at which it is called salt of tartar.

On filtering the solution to separate what had been deposited by cooling, no change was produced in the filtered liquor by mineral alkali; but mild vegetable alkali produced a cloudiness, which was instantly taken up on adding mineral alkali and lime-water. Neither Prussian alkali, nor the acids of arsenic, tartar, sugar, or borax, nor any of the three mineral acids, had any effect upon it.

1466 Experiments with nitrous acid.

2. An hundred and twenty grains of the same calculus were put into a tubulated glass retort, and half an ounce of strong nitrous acid poured upon it. An effervescence immediately ensued; and some part of the extricated aerial fluid being perserved, appeared to be fixed air mixed with a small quantity of nitrous air. When the effervescence ceased, a quarter of an ounce more of nitrous acid was added. On digesting the mixture upon hot sand for an hour, it emitted nitrous vapour and nitrous air; but the latter in very small proportion. When the solution was completed, the whole was poured into a small matrass, and gently boiled till the superabundant nitrous acid was nearly expelled. The solution was of a deep yellow colour and turbid; but on adding five ounces more of water, and digesting it for a quarter of an hour longer, it acquired the colour and consistency of dephlogisticated nitrous acid. On cooling it became somewhat turbid, and in a few days deposited a darkish yellow powder; which, when separated, washed, and dried, weighed little more than a quarter of a grain, and, on examination, was found to be a calx of iron.

1467 Crystallizes on exposure to the sun.

Our author being desirous to know what effect the sun would have upon it, placed it in a window where the sun shone full upon it for four hours every day. Here a little moisture seemed daily to exhale from it, the weather being hot, and the matrass, which had a short wide neck, being only covered, with bibulous paper to keep out the dust. In this situation, in the course of a week, a few very small crystals appeared to float upon the surface. These in time fell to the bottom, where they adhered together so as to form a hard concretion, still retaining a crystalline appearance, but so small and confused, that it was impossible to distinguish their figure; and this deposition of crystals continued for a month, after which it seemed to cease. The solution was then filtered to separate the salt; after which one-half of the liquor was evaporated away, and the rest set in the usual place for a fortnight longer, but no more crystals appeared. The salt, which weighed three grains, was then digested in four ounces of distilled water; but no part seemed to be dissolved. Three ounces of the water were then decanted off, and six drops of vitriolic acid added to the remainder, which by the help of digestion seemed to dissolve the salt slowly; but on adding half an ounce more distilled water, the whole was readily taken up. Acid of sugar had no effect on this solution; but lime-water rendered it turbid. The whole was then precipitated with caustic volatile alkali, and the solution filtered, which likewise threw down the lime from lime-water. The precipitate was then washed, and distilled vinegar poured upon it, which did not take it up; but it was dissolved by marine acid. Phlogisticated alkali had no effect upon it; and the acid of sugar occasioned very little cloudiness after standing three or four hours; from which our author supposed that the matter was phosphorated clay.

The solution, being now free from iron and phosphorated clay, had a subacid taste, and looked clearer, though still retaining a yellow cast. Acid of sugar had no effect upon it; but nitrated terra ponderosa threw down a precipitate, as did likewise the caustic volatile alkali. Mild vegetable alkali caused no precipitation; which our author attributed to the solution of the manganese and clay by the fixed air extricated from the alkali. Two-thirds of the solution were then put into a small glass retort, and two ounces distilled off, which had no taste, but smelled very agreeably, and not unlike rose-water. After all the liquor had passed over, white fumes appeared in the retort, and these were soon followed by an aerial fluid. On collecting some of this, a candle was found to burn in it with an enlarged flame. Nitrous air did not diminish it in the least; and it seemed to be that species of air into which nitrous ammoniac is convertible. No more than 13 or 14 inches of this kind of air could be obtained; and as soon as it ceased to come over, crystals were observed in the lower part of the neck of the retort. On augmenting the heat, a white salt began to sublime and adhere to the upper part of the retort; the operation was continued until the retort was red-hot; but, on breaking it, the quantity of sublimate was so small, that very little of it could be collected; though, from the small quantity obtained, our author was convinced of its being the same in quality with what was obtained in the former analysis. The salt which crystallized in the neck of the retort was nitrous ammoniac, as appeared from its detonation *per se*, &c. A grey powder was left in the bottom of the retort, which hot distilled water partly dissolved; muriated terra ponderosa, acid of sugar, and vegetable alkali, rendered this solution turbid: but caustic volatile alkali had no effect upon it. The remaining part of the powder which was left by the distilled water, readily dissolved with effervescence in the marine acid, and was precipitated by caustic volatile alkali; the part soluble in distilled water appearing to be gypsum, and that soluble in marine acid to be magnesia.

From all these experiments, Mr Higgins concludes the composition of the human calculus to be vastly different

Calculus. ferent from what either Mr Scheele or Mr Bergman have ſuppoſed it to be. "It appears (ſays he), that the calculus was compoſed of the following different compounds blended together; *viz.* ſelenite, alum, microcoſmic ſalt, mild volatile alkali, lime, and cauſtic volatile alkali, combined with oil, ſo as to form a ſaponaceous maſs; calx of iron, magneſia combined with aerial acid, clay-enveloped by a ſaponaceous and oily matter, and the ſublimate already deſcribed." Conſidering this to be the true ſtate of the calculus in the bladder, the ſmall proportions of clay, ſelenite, magneſia, and iron, which are the moſt inſoluble of the ingredients; the great ſolubility of microcoſmic ſalt and alum, and the miſcibility of lime, volatile alkali, and oil, in water; tend to ſhow, that the ſublimate is the cementing ingredient. Indeed, its inſolubility in water, and property of forming nuclei out of the body, as above obſerved, leave no room to doubt it. The proportion of the other ingredients, and very likely their preſence, depend upon chance, volatile alkali and oil excepted; therefore this ſublimate ſhould be the object of our inveſtigation.

1468 Higgins's account of the conſtituent parts of calculus.

1469 Remarks on the remedies proper for diſſolving it.

Mr Higgins concludes his diſſertation with ſome practical remarks concerning the remedies proper for diſſolving the ſtone, for counteracting that diſpoſition in the body which tends to produce it, and concerning the regimen proper for thoſe who are to undergo the operation of cutting for it. "The effect of mild mineral alkali (ſays he) on the ſublimate, is well worth the attention of thoſe who may have an opportunity of trying its efficacy. Mild mineral alkali may be taken in large doſes, and continued for a length of time with impunity to the moſt delicate conſtitutions, only obſerving a few circumſtances; but this alkali, in a cauſtic ſtate, muſt very often be attended with miſchievous conſequences. Beſides, if we conſider that it muſt enter the maſs of blood before any part can reach the bladder, and the ſmall portion of the doſe taken ſecreted with the urine, and, laſtly, the action of cauſtic alkali upon animal ſubſtances; we ſhall be at a loſs to know on what principle cauſtic alkalies have been recommended in preference to mild. Soap itſelf might as well be recommended at once; for ſoon after cauſtic alkali is taken, it muſt be in a ſaponaceous ſtate. Fixed vegetable alkali ſhould be avoided, and the perference given to the other two alkalies. As it is evident that alkalies have no real action on the ſtone in the bladder, though their efficacy has been experienced in alleviating the diſeaſe when timely adminiſtered, their mode of action is only explicable in the following manner: They either prevent the generation of the ſublimate in the ſyſtem, or elſe keep it in ſolution in the maſs of fluids: and being in the utmoſt degree of diviſibility, its ultimate particles are capable of paſſing through the moſt minute emunctories; by which means it is carried off by other ſecretions as well as the urinary. Thus urine, not being ſaturated with this matter, acts as a ſolvent on the ſtone; and as the moſt ſoluble parts are firſt waſhed away, it falls through time into fragments of irregular ſurfaces, which by their friction irritate and inflame the bladder, as has been obſerved by ſeveral practitioners.

"Allowing that the ſublimate is the cementing ſubſtance in the calculus, and judging, from the effects of alkalies upon it, their *modus operandi* in the conſtitution, it remains now to inquire into the origin of the calculus. Mr Scheele has found this ſublimate in the urine of different perſons; and hence inferred, that it was a common ſecretion; but it ſtill remains to be aſcertained, whether there be a greater quantity of it procured from the urine of patients who labour under this diſorder than in thoſe who do not? If this ſhould not be the caſe, may not a deficiency of volatile alkali in the conſtitution be the cauſe of the concretions in the kidneys, bladder, &c.; or, which muſt have the ſame effect, too great a proportion of acid, which, uniting with the alkali, may take up that portion which would have kept the ſublimate in ſolution until conveyed out of the ſyſtem by the urinary and other ſecretions; and may not this be the phoſphoric acid? If this latter ſhould be the caſe, an increaſe of microcoſmic ſalt muſt be found in the urine; but if the former, a decreaſe of the volatile alkali, and no increaſe of the neutral ſalt. The ſmall quantity of phoſphoric acid found in the calculus proceeds from the ſolubility of microcoſmic ſalt. Do not volatile alkali and phoſphoric acid conſtitute a great part of the human frame? and is their not a proceſs continually carried on to generate theſe in the ſyſtem? and is not this proceſs liable to be retarded or checked by intemperance, &c. which may vary their quantities and proportions? and may not a due proportion of theſe be neceſſary to a vigorous and ſound conſtitution? If ſo, no wonder that an increaſe or deficiency in either or both of theſe ſhould be productive of ſeveral diſorders."

On this ſubject, however, our author has not had ſufficient leiſure to make the experiments neceſſary for its elucidation. Indeed, it ſeems not eaſy to do ſo; as, in his opinion, at leaſt 500 would be required for the purpoſe. "That the urinary ſublimate is preſent in tubercles found in the lungs of perſons who die of pulmonary conſumptions, and likewiſe in what are vulgarly called *chalk ſtones*, is what I have experienced: but in what proportion, or whether in quantities ſufficient to cauſe the concretion, is what I cannot ſay; for I have had but a few grains of each to examine. I have every reaſon to ſuſpect, that conſumptions and ſcorbutic complaints very frequently ariſe from a ſuperabundance of this ſublimate in the ſyſtem; and that it is chiefly the cauſe of the gout and rheumatiſm, and ſolely the cauſe of the ſtone in the bladder. I make no doubt but theſe diſorders generally proceed from obſtructions: and it is probable, that either a precipitation of this ſublimate in the ſyſtem, or elſe a deficiency of ſome other ſecretion, which would hold it in ſolution until conveyed out of the body, may be the chief cauſe of thoſe obſtructions; and likewiſe, that different degrees of precipitation may produce different ſymptoms and diſorders.

1470 Sublimate of calculus found in conſumptive and gouty people.

"That mineral or volatile alkali and bark have been uſeful in the above diſorders, has been affirmed by experienced phyſicians; and I know an inſtance myſelf of mineral alkali and nitrous ammoniac being ſerviceable in a pulmonary complaint of ſome ſtanding.

"With reſpect to the ſtone, when it acquires a certain magnitude, it is abſurd to attempt to diſſolve it in the bladder, it waſtes ſo very ſlowly; and during this time the patient muſt ſuffer vaſt pain, particularly when

Vitriolic ether.

when the ſtone acquires a rugged ſurface: therefore cutting for it at once is much preferable.

"Mineral alkali taken in the beginning of the complaint, and before the ſtone accumulates, will no doubt check its progreſs, and may in time change that diſpoſition in the habit. Patients who are cut for the ſtone ſhould, I think, take mineral alkali for ſome time when the wound is healed, but not before, for fear of bringing on a mortification."

Nitrous acid.

APPENDIX;

Containing ſuch DISCOVERIES as have appeared ſince the Compilation of the Article, and which could not be inſerted in their proper Places.

I. *Vitriolic Ether.*

1471 Various methods of rectifying vitriolic ether.

M. PELLETIER formerly propoſed a method of rectifying this fluid by putting mangaueſe into the veſſels; but as the vitriolated manganeſe might perhaps communicate ſome injurious quality, another method is propoſed by M. Tingry. After firſt drawing off the ether, he adds a diluted ſolution of volatile alkali, and avoids as much as poſſible the diſſipation of the vapours: the ether is then rediſtilled. It may afterwards in this way be waſhed more ſafely, and with leſs loſs. The little proportion of the ether which is ſeparated in the water, may be again recovered, or the water may be again employed for the ſame purpoſe. M. Lunel propoſes calcined magneſia for this purpoſe, as its ſalt is not ſoluble; though perhaps pure terra ponderoſa might be better.

II. *Nitrous Acid.*

1472 Mr Higgins's obſervations.

ON this ſubject Mr Higgins has ſeveral curious and intereſting obſervations. "It is not an eaſy matter (ſays he), to aſcertain exactly the greateſt quantity of dephlogiſticated air, which a given quantity of nitrous acid may contain. I always found nitre to vary, not only in its product of phlogiſticated and dephlogiſticated air, but likewiſe in their proportion to one another. The pureſt nitre will yield, about the middle of the proceſs, dephlogiſticated air ſo pure as to contain only about $\frac{1}{15}$ of phlogiſticated air. In the beginning, and nearly about the latter end of the proceſs, air will be produced about twice better than common air. On mixing the different products of a quantity of pure nitre, it was found that, by expoſure to liver of ſulphur, $\frac{1}{6}$ part was left unabſorbed; and this was the utmoſt purity in which I obtained dephlogiſticated air from nitre.

1473 Account of its conſtituent parts by M. Lavoiſier.

"According to M. Lavoiſier, 100 grains of nitrous acid contain $79\frac{1}{3}$ of dephlogiſticated air, and $20\frac{2}{3}$ of phlogiſticated air, which is not quite four to one. But his experiments contradict this; for whatever mode he adopted to decompoſe nitrous acid, it appeared that the proportion of dephlogiſticated air was nearly as five to one of phlogiſticated air.

1474 By Mr Cavendiſh.

"Mr Cavendiſh has proved, that nitrous acid may be formed by taking the electric ſpark in a mixture of three parts of phlogiſticated air, and ſeven of dephlogiſticated air, which is but $\frac{1}{7}$ more of dephlogiſticated air than nitrous air contains; which may apparently contradict M. Lavoiſier's, as well as my own, eſtimation of the proportion of the conſtituent principles of nitrous acid, when in its perfect ſtate. The red nitrous vapour contains three parts of nitrous air and one of dephlogiſticated air, or one of phlogiſticated and three of dephlogiſticated air; but nitrous vapour may be formed with a leſs proportion of dephlogiſticated air; and which, though it may not be ſo condenſible as a more perfect nitrous vapour, yet will, when in contact with pure alkali, unite with it, and form nitre, as was the caſe in the experiment of Mr Cavendiſh. The common ſtraw-coloured nitrous acid contains more dephlogiſticated air than the red nitrous acid or vapour; the proportion appears to be about four to one; but the colourleſs contains about five of dephlogiſticated to one of phlogiſticated air.

1475 Method of obtaining colourleſs nitrous acid.

"Having once a charge of nitrous and vitriolic acid in a green glaſs retort, I put it in a ſand-pot to diſtil; but the pot being ſmall, the edge came too near the retort, about a quarter of an inch or more above the charge; which, before the proceſs commenced, and when it acquired more than the heat of boiling water, cracked it all round in that direction. Being thus ſituated, I was obliged to withdraw the fire, and, before the charge got cold, to ladle it into an earthen pan. On introducing it into a freſh retort, I obtained from it nitrous acid nearly as colourleſs as water. The vitriolic acid uſed in this proceſs not being very perfect, the goodneſs of the nitrous acid was attributed to the purity of the nitre from whence it was diſtilled; but in another proceſs, though the ſame nitre was uſed with much purer vitriolic acid, the produce was of an high ſtraw colour. On recollecting the abovementioned circumſtance, the vitriolic acid and nitre were next mingled in due proportion, and expoſed in an earthen pan ſet in ſand, to nearly the heat of boiling water, for half an hour or more, continually expoſing freſh ſurfaces to the air. When the charge was quite cold, I introduced it into a retort, and diſtilled as colourleſs nitrous acid as the former. As no nitrous air was emitted during digeſtion, it muſt have imbibed dephlogiſticated air from the atmoſphere."

1476 How to ſet charcoal on fire by means of nitrous acid.

Mr Prouſt found, that ſtrong nitrous acid will ſet fire to charcoal if it be rendered very dry. He likewiſe remarked, that charcoal expoſed to the air a few hours after calcination, was unfit for the experiment. Charcoal, he obſerves, attracts moiſture very forcibly. The firſt effect of the charcoal on the nitrous acid, he obſerves, is to withdraw a portion of its water from it; by which it is rendered highly concentrated, at the ſame time that the condenſation of the water heats the charcoal in a ſmall degree, but ſufficiently to volatilize a nitrous vapour; which, as ſoon as it reaches that portion of dry charcoal next the humid part, is condenſed

Nitre. densed by it, and generates heat enough to promote the decomposition of the nitrous acid. Hence we see why the experiment will not succeed if the acid be poured on the surface of the charcoal.

1477 Effect of nitrous acid on blood. The effect of nitrous acid on blood, according to Mr Higgins, is very singular. Two parts of blood procured fresh at the butchers, one of strong nitrous acid, and about one fifth of the whole of water, were digested in the heat nearly of boiling water (fresh portions of water being occasionally added until the whole of the acid was expelled), when it acquired almost the colour, and exactly the taste, of bile. When mixed with a large quantity of water, it acquired a fine yellow colour; and, on standing, deposited a substance of a brighter yellow, though the supernatant liquor still retained a yellow colour and bitter taste, but not so intensely as when the precipitate was suspended in it. The different stages of this process were well worthy of observation. No nitrous air was produced, and the acid was expelled in the state of a white vapour. The liquor was found to increase in bitterness as the acidity vanished. About the middle of the process, the solution first tasted acid, but was quickly succeeded by a bitter sensation. It appears that the nitrous acid took dephlogisticated air from the blood; for though red nitrous acid was used, it was expelled in a perfect state.

III. *Nitre.*

Though the artificial generation of the nitrous acid, from a mixture of dephlogisticated and phlogisticated air, is now sufficiently understood, yet we do not well know in what manner nature performs the operation. Some chemists, particularly M. Thouvenal, have found, that putrefaction favours the production of nitrous acid. All animal substances, during their decay, give out a vast quantity of phlogisticated air; therefore, if dephlogisticated air be present, it will unite to the phlogisticated air in its nascent state, and form nitrous acid: but Mr Higgins has observed, that

1478 Nitre generated without putrefaction. nitrous acid may be generated in plenty where there is no putrid process going on. "The chemical elaboratory at Oxford (says he) is near six feet lower than the surface of the earth. The walls are constructed with common limestone, and arched over with the same; the floor is also paved with stone. It is a large room, and very lofty. There are separate rooms for the chemical preparations, so that nothing is kept in the elaboratory but the necessary implements for conducting experiments. There is an area adjoining it on a level with the floor, which, though not very large, is sufficient to admit a free circulation of air. The ashes and sweepings of the elaboratory are deposited in it. There is a good sink in the centre of this area, so that no stagnated water can lodge there. Notwithstanding all this, the walls of the room afford fresh crops of nitre every three or four months. Dr Wall, who paid particular attention to this circumstance, and who told me it contained fixed vegetable alkali, requested I would analyse it, and let him know what it contained. I found that two ounces of it contained six drachms of nitrated fixed vegetable alkali, and three of calcareous nitre. The nitre first appears in small whitish filaments as fine as cob-web, which, when they get a little larger, drop off; so that they never acquire sufficient growth to distinguish their figure to a naked eye. On finding that they contained fixed vegetable alkali, I concluded that it proceeded from minute vegetation; but in this I was mistaken; for I found that they were soluble in water, and that they detonated with charcoal at every stage of their growth. Having swept this saline efflorescence from the wall, I dug deep into it, but could not obtain nitre from it. When a part had been white-washed, it yielded nitre, but not so abundantly as a neighbouring spot which had not been treated in the same manner. Hence it is evident, that nitrous acid may be formed without the assistance of putrescent processes in a still damp air, where there is a substance to attract it when half formed, whereby it is in time brought to perfection. The above facts moreover prove, that fixed vegetable alkali is a compound."

IV. *Marine Acid.*

Marine acid.

1479 Unsuccessful attempts to decompose sea-salt

Mr Higgins informs us, that he has, with a view to decompose sea-salt, mixed it with manganese in various proportions, and exposed them in a reverberating furnace in a well closed crucible for three hours, to a heat nearly sufficient to melt cast iron. In the same manner he treated manganese, salt, and charcoal, as well as clay, salt, and charcoal, and salt and clay alone, with very little success. He treated calcined bones, salt, and charcoal, and calcined bones and salt, as well as lime and salt, in the same manner, without effecting any apparent change in the salt. He was informed, however, by Mr Robertson, apothecary in Bishopsgate-street, that he had partially alkalized it, by exposing it with clay to a fierce heat; but that soon after it got into contact with air, it became neutral again. "If common salt and litharge be fused (says Mr Higgins), it is in part decomposed; the acid suffers no decomposition, but unites with the lead; whereby it acquires, when the saline matter is washed away, a yellow colour. It is evident (adds he) from these facts, that the basis of marine acid is a combustible body, and quite different from light inflammable air, charcoal, or any known inflammable substance; and that it attracts dephlogisticated air with greater force than any substance hitherto discovered. Though charcoal will decompose all other acids, except a few, when united to bodies which will fix them until they acquire a sufficient degree of heat, yet it has no effect upon marine acid."

According to Fourcroy, if alkaline air be confined by mercury, and dephlogisticated marine acid air be added to it (which must be done quickly, as the acid air would dissolve the mercury), each bubble produces a slight detonation, and furnishes a very amusing spectacle.

1480 Method of distilling spirit of salt with clay.

Though in Britain the distillation of the spirit of salt with clay has long been entirely laid aside for the process with oil of vitriol, yet it is still practised in other countries, and may be effected in the following manner: Having previously decrepitated the salt, and dried the clay, they are then to be ground, mixed, and sifted together. The mixture is next to be worked with a spatula, and then with the hands, until it is brought into a moderately stiff and uniform mass.

This is to be divided into balls about the ſize of a pigeon's egg, ſo that they can paſs through the neck of the retort; but before they are put into the diſtilling veſſel, it is proper to dry them thoroughly. The retorts muſt be of ſtone-ware, and carefully coated, in order to prevent them from breaking with the intenſe heat to which they are expoſed. They are to be filled two-thirds full of materials, and the diſtillation muſt be performed in a reverberatory furnace. The receiver at firſt is not luted on, becauſe that which riſes in the beginning of the diſtillation, being very aqueous, is to be put by itſelf. When this has come over, another receiver is then to be applied, and cemented with fat lute, and covered with a cloth daubed with a mixture of lime and the whites of eggs. The heat is to be raiſed until the retort is red-hot, and continued in this degree until the diſtillation ceaſes.

Various proportions of clay and ſalt have been recommended for this proceſs; but it ſeems probable that not leſs than ten parts of clay to one of ſalt, as Pott has directed, will be found neceſſary. Inſtead of the clay, ſome direct the uſe of bole; but this is inconvenient on account of the iron it contains. Powdered talc has alſo been recommended, but this is not always free from iron; and where a very pure ſpirit is wanted, there is a neceſſity for having recourſe to oil of vitriol, and glaſs or ſtone-ware veſſels. As the marine acid cannot be ſeparated from the earthy mixtures abovementioned, but by means of moiſture, M. Beaumé adviſes to moiſten the reſiduum, and repeat the diſtillation, by which more acid will be obtained.

1481 **Effect of marine acid upon phlogiſtic matters.**

As the marine acid has very little action upon phlogiſtic matters, it cannot therefore affect oils, either expreſſed or eſſential, in a manner ſimilar to the vitriolic or nitrous. M. Marges, however, has obſerved yellow cryſtals reſembling amber formed in bottles, containing a mixture of oils and marine acid of moderate ſtrength, which had ſtood for ſeveral months. The little effect which the marine acid has upon theſe ſubſtances was firſt ſuppoſed to be owing to its want of phlogiſton in itſelf; but when it was afterwards found, that, by the application of certain ſubſtances which have a great attraction for phlogiſton, the marine acid was rendered capable of uniting very readily with inflammable matters, the former theory was abandoned. It was now aſſerted, that the acid, inſtead of containing no phlogiſton, was naturally endowed with a very conſiderable quantity; and that, in its new ſtate, it was dephlogiſticated by the ſubſtances applied. On the other hand, the antiphlogiſtians aſſerted, that no change was thus made upon it, farther than adding a quantity of pure air, which they ſuppoſe to be the baſis of all acids. On this ſubject, however, M. Cornette maintains, that the marine acid ſeems to have ſo little action upon inflammable ſubſtances, merely becauſe it is weaker than the reſt; and likewiſe that it is often previouſly combined with ſome inflammable matter, by which its attraction is prevented. He maintains, that if the marine acid be concentrated in ſuch a manner as to render its ſpecific gravity to that of water as 19 to 16, it will then act upon oils with heat and effervеſcence, reducing them to a black and thick ſubſtance, and even burning them to a kind of coal. Some experiments have been made by Mr Haſſe, with a view to inveſtigate the action of the marine and vitriolic acids upon balſams and oils; for which purpoſe he mixed two drachms of ſmoking ſpirit of ſalt with one of each of the oily ſubſtances to be tried. The reſults were, that Canada balſam gained one ſcruple in weight; balſam of capivi 19 grains; ſtorax, and Venice turpentine, each one ſcruple; aſphaltum 18 grains; but the eſſential oils of aniſe-ſeed, benzoin, bergamot, coriander, and many others, were not altered in any degree. The action of this acid upon inflammable matters, however, is augmented by its being reduced into the form of air.

Gmelin relates, that, by diſtilling a mixture of five parts of ſalt, twelve of ſpirit of wine, and four of vitriolic acid, to which he had previouſly added one or two parts of water, he obtained a completely dulcified ſpirit of ſalt, and an imperfectly dulcified ſpirit of vitriol, upon rectifying the liquor.

1482 **Glaſs corroded by it.**

Homberg found, that glaſs was corroded by the marine acid: and his obſervation has been confirmed by Dr Prieſtley; who finds that its corroſive power is augmented by confining the acid in tubes hermetically ſealed. Its power is exerted not only on flint-glaſs, but even on common green glaſs; though more powerfully on the former, where it chiefly attacks the red-lead uſed in its compoſition. By incloſing marine acid gas for ſome weeks in a glaſs tube expoſed to heat, an incruſtation was formed on the inſide, while the air was diminiſhed to $\frac{1}{8}$ of its original bulk, one half of which was abſorbed by water; the other was phlogiſticated air.

1483 **Cauſe of the yellow colour of marine acid.**

The marine acid is generally met with of a yellow or reddiſh colour, which by Macquer is given as one of its characteriſtic marks. In general, however, this colour is thought to proceed from iron; but Dr Prieſtley has found that it may be produced by many different ſubſtances; and his obſervations have been confirmed by Scheele and other chemiſts. The Doctor is of opinion that it is occaſioned for the moſt part, if not always, by a mixture of earth; and he was able to communicate it by means of calcined oyſter-ſhells, calcined magneſia, pipe-clay, or pounded glaſs; but not by wood-aſhes, from whence the air had been expelled by heat. It was effectually diſcharged by flowers of zinc, a coal of cream of tartar, and by liver of ſulphur; but he found that the colour which had been diſcharged by liver of ſulphur, would return by mere expoſure of the acid to the atmoſphere, but not that which had been diſcharged by flowers of zinc.

Dephlogiſticated ſpirit of ſalt.

1484 **Expeditious method of bleaching linen.**

When the action of this vapour upon any thing is to be examined, the ſubſtance muſt be put into a bottle in ſuch a manner as to remain in contact with it; or it may be put into a glaſs tube, which is ſuſpended and fixed to the ſtopper, and thus introduced into the bottle.—From its property of deſtroying all vegetable colours, it promiſes to be of very conſiderable uſe in the arts, provided it could be had in ſufficient quantity, and cheap. It bleaches yellow wax, and when properly applied to linen, will whiten it ſufficiently, and without injury in a few hours. This may be effected by ſteeping the linen for that ſpace of time in water impregnated with the dephlogiſticated marine gas. It unites with this fluid rather more eaſily than fixed air.

Ber-

Marine acid.

Berthollet, in order to impregnate water with it without exposing the operator to the fume, which is extremely disagreeable, put the mixture of marine acid and manganese into a retort. To this he applied first an empty bottle, and then several others filled with water, and communicating with each other by means of bent tubes; surrounding the whole with ice. When the water in the bottles was saturated, the gas became concrete, and fell to the bottom; but with the smallest heat it arose to the top in bubbles. The specific gravity of the saturated water was to that of distilled water, when the thermometer was only five degrees above the freezing point, as 1003 to 1000. This impregnated water is not acid, but has an austere taste, and has the same action as the gas, though in a weaker degree. Mr Berthollet has observed, that the addition of alkalies does not prevent, but rather promotes, the discharge of colours; for which reason he directs to add a fixed alkali to the impregnated water in which linen is to be steeped for bleaching. This is the expeditious method hinted at under the article BLEACHING; but which has not hitherto come into use, principally through the high price of the dephlogisticated gas.

The dephlogisticated marine acid does not discharge all colours with equal ease. Those of litmus and syrup of violets are entirely destroyed, and turned white. The colouring matter of Brazil-wood, and some green parts of plants, retain a yellow tint. The leaves of evergreen plants resist its action for a long time, and at last only acquire the yellow colour which they assume by long exposure to the air; and in general the changes of colour which vegetable matters suffer from this gas, are similar to those which take place on long exposure to the air; and by this operation the gas is converted into common marine acid.

1485 Effect of the dephlogisticated acid on phlogistic matter, &c.

Oils and animal fats are thickened by this gas; and by these and other inflammable substances it is reduced to the state of common marine acid. Light is said to produce the same effect. It unites with fixed alkalies and calcareous earths, but without any sensible effervescence; and thus they lose their peculiar taste and colour. M. Berthollet having boiled in a retort, to which a pneumatic apparatus was affixed, some of the dephlogisticated marine acid liquor with mineral alkali, thus obtained a considerable quantity of elastic fluid, composed partly of fixed air, partly of the air contained in the vessels, and partly of air considerably purer than that of the atmosphere. The result of the combination was common salt. On repeating the experiment with lime, no fixed air was obtained; but that which came over became gradually more and more dephlogisticated. Volatile alkali, even when caustic, occasioned an effervescence, and emitted a peculiar kind of air, which was neither fixed nor dephlogisticated, but of a peculiar kind.

Green vitriol is changed to a red by the dephlogisticated gas, but the colour of blue and white vitriol is not affected. By the assistance of light, it acts upon phosphorus, and the result is phosphoric and common marine acids. It does not dissolve ice nor camphor; in which respects it differs from the common marine acid gas.

1486 Marine ether.

On mixing marine acid, manganese, and spirit of wine, and distilling them with a very gentle heat, little air of any kind is produced, but a quantity of ethereal liquor very slightly acid. The proportion used by Pelletier were an ounce and a half of manganese, five ounces of concentrated marine acid, and three ounces of spirit of wine. "In this process (says Mr Kier), the whole of the dephlogisticated acid seems to have united with the spirit of wine, and to have formed ether. The difficulty of combining marine acid with spirit of wine, so as to form an ether, is well known, and though there have been some approximations to it, yet the only instances in which it has been completely effected, have succeeded in consequence of the marine acid being dephlogisticated; by which its action on spirit of wine, as well as on all inflammable matters, is greatly increased."

M. Pelletier has observed, that when we put a bit of phosphorus into dephlogisticated marine gas, the former is immediately dissolved, and a light is perceived, the vessel being filled at the same time with white vapours. He has likewise observed, that sea-salt, with an excess of pure air, thrown into heated vitriolic acid produces a small detonation. To make this salt in quantity, take, for instance, ten pounds of sea-salt, mixing it with from three to four pounds of manganese, pour on the mixture ten pounds of vitriolic acid, and distil with Woulfe's apparatus. Pass the disengaged acid through a solution of fixed vegetable alkali, either caustic or otherwise. A little more than ten ounces of the new marine salt with excess of pure air is obtained, and a quantity of salt of Sylvius, or digestive salt. The salt with excess of pure air crystallizes first, and by means of repeated crystallizations, is entirely disengaged from the other. 1487 Method of procuring a detonating salt from the acid in quantity.

V. *Aqua Regia*.

1488 Various ways of preparing aqua-regia.

THIS acid, which is named from its property of dissolving gold, is compounded of the nitrous and marine acids. Gold and platina cannot be dissolved in any other menstruum, nor can regulus of antimony and tin be so easily dissolved by any other as aqua-regia. It may be made various ways. 1. By adding the two acids to each other directly. 2. By dissolving in the nitrous acid some salt containing marine acid, particularly sal ammoniac and common salt. 3. By distilling nitrous acid from either of these salts. And, 4. In Dr Priestley's method of impregnating marine acid with nitrous acid vapour.

1489 Differences between these acid liquors.

The only difference between those liquors prepared by the methods abovementioned is, that when sal ammoniac or sea-salt are dissolved in the nitrous acid, the aqua-regia contains a quantity of cubic nitre, or nitrous ammoniac, which, tho' it cannot much affect the acid as a solvent, may make a considerable difference in the nature of the precipitate. Thus, gold precipitated from an aqua-regia formed by the pure nitrous and marine acids, does not fulminate, though it does so when precipitated from one made with sal ammoniac. There are no established rules with regard to the proportions of nitrous and marine acids, or of nitrous acid and sal ammoniac, which ought to be employed for the preparation of aqua-regia. The common aqua-regia is made by dissolving four ounces of sal ammoniac in 16 ounces of nitrous acid; but these proportions must be varied, according to the nature of the intended solution.

Borax. tion. Platina, for inſtance, is diſſolved in the greateſt quantity by equal parts of the two acids; regulus of antimony by four parts of nitrous acid to one of marine; and, in general, the greater the quantity of marine acid employed in the mixture, the leſs are the imperfect metals, particularly tin, calcined or precipitated by it. A mixture of two parts of ſpirit of nitre, and one of ſpirit of ſalt, diſſolves nearly an equal weight of tin into a clear liquor, without forming any precipitate; but, for this purpoſe, the operation muſt be conducted ſlowly, and heat avoided as much as poſſible.

VI. *Borax.*

In a memoir in Crell's Chemical Annals, by M. Tychſon, the author ſhews, by different experiments,
1490 Methods of purifying borax. that it may ſometimes be purified by ſolution, filtration, and evaporation only; but that ſometimes the operation is more eaſy and effectual by previous calcination; but then the product is a little leſſened, eſpecially if the calcined maſs be not well powdered, and then boiled ſufficiently in water. Powder of charcoal, he ſays, may be ſometimes advantageouſly employed in the purification; but in general there is no difference between the crude and purified borax, except in the addition of extraneous matters; at leaſt, as the quantity of acids is the ſame, the addition of mineral alkali is uſeleſs: theſe extraneous matters are an animal fat, and a ſand compoſed of clay, lime, and a martial earth. If the oily matter of tartar be ſeparated by paſſing the lixivium through a ſtratum of clay, as is ſuppoſed in the preparation of the cryſtals at Montpelier, it would ſuggeſt a method of greatly abridging the proceſs of the purification of borax.

VII. *Acid of Borax, or Sedative Salt.*

1491 Methods of preparing the ſedative ſalt from borax. On the preparation of this ſalt Mr Beaumé obſerves, that a little more acid ought to be added to the borax than what is juſt ſufficient to ſaturate its alkaline baſis. Unleſs this be done, the ſedative ſalt remains confounded with the other ſaline matters in the ſolution, and of conſequence the cryſtallization muſt be diſturbed. The ſalt, though formed in an acidulated liquor, is eaſily deprived of its ſuperfluous acid by draining upon paper. It does not cryſtallize as ſoon as the ſtronger acid ſeparates it from its baſis, even tho' the ſolution of borax had been previouſly made as ſtrong as poſſible; but this delay is occaſioned by the heat of the liquor; for as ſoon as it cools, a conſiderable quantity of cryſtals is formed.

1492 Its properties. The acid of borax does not fall into powder when expoſed to the air, but rather attracts a little moiſture from it. Its taſte is at firſt ſomewhat ſouriſh, then cooling and bitteriſh; and laſtly, it leaves an agreeable ſweetneſs on the tongue. It makes a creaking ſound, and feels a little rough between the teeth; and when vitriolic acid is poured upon it, exhales a tranſient odour of muſk. It is ſoluble, according to ſome chemiſts, in the proportion of one to 20 in cold water, or of one to eight in boiling water. Wenzel informs us, that 960 grains of boiling water diſſolve 434 of the ſalt; while, on the other hand, Morveau aſſerts, that he could diſſolve no more than 183 grains in a pound of diſtilled water. Rouſs informs us, that fixed air Acid of borax and its combinations. prevents the ſolution of the ſalt in water, and Morveau, that its ſolubility is much augmented by cream of tartar. When previouſly made red hot, it diſſolves in water with a ſmell of ſaffron, and a grey powder of an earthy appearance is precipitated, which is ſoluble in vitriolic and marine acids, and may be again precipitated in the form of ſedative ſalt.

Phlogiſticated alkali makes no change on ſedative ſalt in ſolution; but paper dipped in a ſolution of it in vinegar, and afterwards dried, burns with a green flame. It is capable of vitrification, though mixed with fine powder of charcoal; and with ſoot unites into a black maſs like bitumen; which, however, is eaſily ſoluble in water, and can ſcarce be reduced to aſhes, but partly ſublimes. By the aſſiſtance of heat it diſſolves in oils, eſpecially thoſe of the mineral kind; and with theſe it yields ſolid and fluid compounds, which gives a green colour to ſpirit of wine. Rubbed with phoſphorus it does not prevent its inflammation; but a yellow earthy matter is left behind. It ſeems alſo to give to white and red arſenic a great degree of fixity, ſo as even to become vitreſcible in the fire; and this property it communicates alſo to cinnabar. When mixed and heated with powder of charcoal, it forms no liver of ſulphur.

Sedative Salt combined,

1. *With volatile alkali.* The produce of this is a peculiar ammoniacal ſalt, which does not evaporate when thrown on burning coals, or otherwiſe intenſely heated, but melts into glaſs of a greyiſh colour, but tranſparent, which cracks when expoſed to the air; and, on diſſolution in water, ſhoots into ſmall cryſtals, which appear to have loſt none of their alkaline baſis. It may be decompoſed by the acetous as well as the mineral acids, and by fixed alkalies and lime.

2. *With magneſia* this acid ſhoots into irregular cryſtalline grains ſoluble in vinegar and acid of ants; in which liquids they cryſtallize like ſmall needles joined together at right angles. They are decompoſed by all other acids, and likewiſe by ſpirit of wine. In the fire, however, they melt eaſily without any decompoſition; and in the dry way ſedative ſalt decompoſes all the earthy ſalts formed by magneſia and any of the volatile acids.

3. *With pure earth of alum,* ſedative ſalt forms a ſalt very difficult of ſolution, when one part of earth is ground with four times its weight of ſedative ſalt and water. The ſame kind of earth, mixed with half its weight of ſedative ſalt, forms a hard grey maſs, reſembling pumice ſtone; part of which is ſoluble in water, and yields a mealy ſediment, together with ſome ſedative ſalt unchanged.

4. *With ſiliceous earth* the ſedative ſalt does not unite in the moiſt way; but, on melting one part of acid with two of this earth, we obtain a frothy, hard, greyiſh-white maſs, from which, however, the acid may be again procured.

5. *Gold* is not acted upon in the wet way by acid of borax; nevertheleſs Rouſs obſerved, that when ſedative ſalt was melted with gold-leaf, it did not vitriſy, but became frothy and hard, did not colour the flame of ſpirit of wine, and only a little of it was ſoluble in water in which ſedative ſalt had been cryſtallized.

A

Acid of borax and its combinations.

A ſolution of borax in which ſedative ſalt was diſſolved, did not precipitate gold.

6. *Platina* is not precipitated from aqua-regia by ſedative ſalt.

7. *Silver* is not affected by melting with an equal quantity of ſedative ſalt; but the latter is vitrified in ſuch a manner as to become inſoluble in water.

8. *Mercury* is not diſſolved either in the dry or wet way; but a ſolution of borax ſaturated with ſedative ſalt precipitates it in a yellow powder from nitrous acid.

9. *With copper.* On this metal ſedative ſalt acts but weakly, even when the ſolution is boiling hot; nevertheleſs, as much of the metal is diſſolved, as gives a little white precipitate on the addition of fixed alkali; but volatile alkali does not throw down a blue precipitate, nor turn the ſolution of that colour. The ſolution of borax precipitates all ſolutions of copper in acids, and then the ſedative ſalt unites with the copper in form of a light green jelly, which, after drying, is of very difficult ſolution in water. Bergman ſays, it is of an agreeable green colour, which it preſerves after being dried; and that, when expoſed to the fire, it melts into a dark-red vitreous ſubſtance. Wenzel aſſerts, that by long continued trituration of copper filings with ſedative ſalt he obtained a ſolution of the metal, which yielded cryſtals on being evaporated. With twice its weight of copper in a covered crucible, an inſoluble vitreous maſs was obtained.

10. *Tin* is not apparently acted upon by boiling with ſedative ſalt; nevertheleſs, the ſolution becomes turbid on the addition of an alkali. By melting the calx with half its weight of ſedative ſalt, we obtain a black maſs like the dark coloured tin ore. By rubbing for a long time filings of tin with ſedative ſalt and water, and afterwards digeſting the mixture with heat for one day, an hard, ſandy, and irregularly ſhaped ſalt was obtained, which, by diſſolution in water, yielded tranſparent, white, polygonous cryſtals; and a ſalt of of the ſame kind was obtained from the ſlag produced by melting equal parts of ſedative ſalt and tin filings.

11. *Lead* is not acted upon directly; but, on adding a ſolution of borax to ſolutions of the metal in vitriolic, nitrous, marine, or acetous acids, the ſedative ſalt unites with the lead. One part of ſedative ſalt with two of minium gives a fine, greeniſh-yellow, tranſparent, and inſoluble glaſs.

12. *With iron.* The acid of borax diſſolves this metal more eaſily than any other. The ſolution is amber-coloured, and yields an ochry ſediment, with cluſters of yellow cryſtals containing a little iron. The metal is precipitated by borax from its ſolutions in vitriolic nitrous, marine, and acetous acids, and the precipitates are ſoluble in ſedative ſalt. A ſolution of iron may alſo be obtained by melting this ſalt with iron filings, and lixiviating the maſs.

13. *Zinc* communicates a milky colour by digeſtion with ſolution of ſedative ſalt. By evaporation it affords a confuſed ſaline maſs, and a white earthy powder by precipitation with alkali. Flowers of zinc, melted with ſedative ſalt, form a light green inſoluble ſlag.

14. *Biſmuth*, in its metallic ſtate, is not acted upon by ſedative ſalt, but is precipitated by borax from a mixture of vitriolic and marine acids, in form of a very white powder, which keeps its colour when expoſed to air, and melts in the fire to a white, tranſparent, and permanent glaſs.

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15. *Regulus of antimony* is not acted upon directly, but its calx is diſſolved when precipitated by borax from a ſolution in aqua-regia.

16. *White arſenic* unites with ſedative ſalt either in the dry or moiſt way, and forms a cryſtallizable compound, forming either pointed ramifications, or white, greyiſh, and yellowiſh ſaline powder.

17. *On regulus of cobalt* the acid has no direct action; but borax precipitates it from its ſolution, and the calx melts with the ſalt into a ſlag of a bluiſh-grey colour; and this, by lixiviation and evaporation, affords a ſedative ſalt impregnated with cobalt, of a reddiſh white colour, and of a ramified form.

18. *Nickel* is precipitated from its ſolution, and the ſedative ſalt unites with it into a ſaline ſubſtance difficult of ſolution.

A variety of opinions have been formed concerning the nature of ſedative ſalt. M. Beaumé and M. Cadet particularly have made a great number of experiments on the ſubject; but as none of theſe have led to any certain concluſion, we forbear to mention them at preſent. Thoſe of Meſſrs Exſchaquet and Struve have indeed eſtabliſhed ſome kind of relation between the acids of borax and phoſphorus, and they have made ſeveral attempts to analize the former, but with little ſucceſs. The moſt remarkable of theſe experiments are the following. 1. They diſtilled, with a ſtrong heat, two parts of phoſphoric acid evaporated to the conſiſtence of honey, one of ſedative ſalt, and two of water. Towards the end of the diſtillation a very acid liquor was obtained; and the reſiduum was a white earth, in quantity above three-fourths of the ſedative ſalt employed, and which, on examination, was found to be the ſiliceous earth; the liquor which paſſed over into the receiver being found to be the volatile phoſphoric acid. If, in this experiment, too much phoſphoric acid be added, a greaſy matter remains; and, if too little, a part of the ſedative ſalt will remain undecompoſed. In their attempts to compoſe borax, they combined phoſphoric acid with mineral alkali, the reſult of which was a compound reſembling borax in many reſpects. When expoſed to the fire it melts into a very fuſible glaſs, which has a mild taſte, and ſeems neutral, but on expoſure to the air, becomes moiſt and acid. On being ſaturated with alkali a ſecond time and vitrified, it again deliqueſces and becomes acid; and the more frequently this operation is repeated, the greater is the reſemblance it bears to borax. In this experiment they ſuppoſed that the alkali was decompoſed, and converted into an earth ſimilar to that of ſedative ſalt.

1493 Experiments made to determine the nature of the ſedative ſalt.

With earthy ſubſtances the reſults were very remarkable. With earth of alum a cryſtallizable ſalt was obtained, which made paper burn with a green flame. Fixed alkali added to a ſolution of this ſalt precipitates an earth, and the ſalt then formed by cryſtallization reſembles borax in ſeveral properties.—In the dry way the earth of alum, with the phoſphoric acid, melts into a glaſs of the ſame fuſibility as that of borax, and like it is fixed in the fire. The ſolution of this glaſs did not cryſtallize. Common

clay

Acid of amber.

clay digested with phosphoric acid produces silky crystals resembling sedative salt. When dried with their mother-water, these give a clear glass, which when united with mineral alkali, has the taste of borax, smells in the same manner, and has the same effect upon metals. With lime, magnesia, and terra ponderosa, this acid produces fusible glasses, insoluble in water, and which communicate a green colour to flame. Earth of bones and selenite mixed with the acid give a white, hard, shining glass, like the best crystal, but fusible as the glass of borax, and which continued flexible after it had ceased to be red-hot. Two parts of gypsum, with one of phosphoric acid, gave a milk white glass fit for soldering metals and enameling. In these experiments, however, it must be remembered, that unless the heat be raised very quickly, the phosphoric acid will be evaporated before any fusion takes place.

VIII. *Acid of Amber.*

It was known to Agricola, that a particular kind of salt could be obtained from amber by distillation; but neither he, nor any succeeding chemist for some time ascertained its acid properties. On the contrary, some erred so far as to imagine that it was a volatile alkali; but, about the beginning of the present century, its acidity began to be generally acknowledged. This property indeed discovers itself by the taste, which is manifestly acid and empyreumatic, along with the peculiar flavour of amber. According to Scheele, also, the aqueous fluid which passes over in the distillation of amber, is an acid resembling vinegar both in taste and chemical properties; and which of consequence ought not to be confounded with the true acid of amber, which manifests qualities of a very different kind.

1494 Methods of purifying the salt of amber.

The properties of salt of amber can hardly be investigated until it has been purified; for which, of consequence, various methods have been proposed. Pott recommends crystallization, after having filtered the solution through cotton-wool, in order to retain the oil. Cartheuser attempts the purification by dissolving the impure salt in spirit of wine, then diluting with six times its quantity of water, and crystallizing the salt. Others recommend sublimation with common salt or sand, and Bergman with pure clay.

The salt of amber dissolves, by the assistance of heat, in nitrous and marine acids, and in the vitriolic without heat. In none of these combinations, however, does it either alter the dissolving acids, or suffer any alteration itself, except that it becomes whiter; with nitre it detonates and flies off; and if the quantity of salt of amber has been greater than that of nitre, the latter is alkalized. Stockar informs us, that it expels the marine acid from sal ammoniac, and sublimes before that salt; with which it does not form any union. When sublimed from common salt, it does not alter the latter in any other respect than giving it a darker colour. It precipitates calcareous earth from its solution in vinegar; and it decomposes sugar of lead; but the precipitate differs from plumbum corneum. It does not prevent the solution of lead in the acids of sea-salt and nitre; nor does it produce any sulphureous smell by calcination with charcoal. Hence it appears that it is neither a vitriolic, nitrous, nor marine acid; and M. Bourdelin must have been mistaken, when he affirms, that, after detonation of this salt with nitre, he obtained a residuum, which tasted like common salt, decrepitated in the fire, yielded crystals of a cubical form, precipitated silver and mercury from the nitrous acid; and thence concluded that it was the same with acid of sea-salt. It is very dear, as only about half an ounce can be obtained from a pound of amber.

Acid of amber and its combinations.

Acid of Amber combined,

1. *With fixed vegetable alkali.* By saturating salt of amber with the fixed vegetable alkali, and then slowly evaporating the solution, we obtain, according to Wenzel, a light deliquescent saline mass; but, according to Stockar, whose experiments are confirmed by those of Mr Keir, the solution abovementioned affords shining white transparent crystals of a triangular prismatic figure, with the terminating points truncated. These crystals readily dissolve in water, deliquesce in the air, and have a peculiarly bitter saline taste. In the fire they decrepitate, melt, and remain neutral; though Wenzel has observed, that with an intense heat they are decomposed and become alkaline. These crystals do not change aquafortis into aqua-regia; and though they precipitate both the solutions of lead and silver, the precipitates are neither plumbum corneum nor luna cornea.

2. *With Mineral alkali.* This combination produces long three-sided columnar crystals, intermixed with some that are foliated. These crystals do not deliquesce in the air, and have a saline, bitter, and smoky taste. They are less soluble than common salt, and melt with more difficulty than nitre. They do not become alkaline on burning coals, and, in their other properties, resemble the former.

3. *With volatile alkali.* This salt shoots into acicular crystals, having a sharp, saline, bitter, and cooling taste; when heated in a silver spoon, they melt and evaporate entirely; in close vessels they sublime. They do not precipitate solution of silver, nor change spirit of nitre into aqua-regis. A powerful antispasmodic remedy is prepared from rectified spirit of hartshorn and salt of amber.

4. *With lime.* This shoots into oblong pointed crystals, which do not deliquesce in the air, and are soluble with difficulty even in boiling water; nor, according to Mr Stockar de Neuforn, can they be decomposed by distillation either with acetous or marine acids. They detonate by distillation with nitrous acid; and are decomposed, either in the moist or dry way, by the vitriolic. When mixed with common sal ammoniac in the dry way, they suffer a decomposition; the succinated ammoniacal salt flying off and the combination of marine acid with lime remaining behind.

5. *With magnesia.* This yields a white, gummy, frothy, saline mass, which acquires a yellowish colour when dried by the fire; and, when cool, deliquates in the air. It is decomposed by alkalies and lime, as well as by the vitriolic acid.

6. *With clay.* By uniting the acid of amber with an edulcorated precipitate of alum with vegetable alkali, Wenzel obtained prismatic crystals, which could not be decomposed by alkalies.

7. *With silver.* The acid of amber has no effect on silver

Acid of amber and its combinations.

silver in its metallic state; but with its precipitate forms thin oblong crystals, radiated and accumulated upon one another, from which the silver may be separated by alkalies, by quicksilver, and by copper.

8. *With copper.* By a long digestion of copper with acid of amber a green solution is obtained, which by mixture with common salt is rendered turbid, by vitriolic acid white, and lets fall a green precipitate on the addition of fixed alkali. Wenzel, however, could not obtain this precipitation by alkalies. His solution yielded groups of green crystals, gave a crust of copper to zinc, and was precipitated by liver of sulphur.

9. *With iron.* Wenzel dissolved a precipitate of this metal in acid of amber, and from the solution obtained small, brown, transparent, and stellated crystals. Zinc precipitated the metal, but not alkalies. From a slightly coloured solution of metallic iron, Pott obtained, by means of alkali, a white precipitate, which soon became yellow, and at length green, by pouring water upon it.

10. *With tin.* Acid of amber dissolves tin when precipitated by a fixed alkali; and the solution yields thin, broad, and foliated transparent crystals. Alkalies throw down but little from this solution; liver of sulphur more; and lead, iron, or zinc, nothing.

11. *With lead.* Acid of amber whitens the surface of lead in its metallic state, but does not dissolve it; neither can lead be precipitated from its solutions in nitrous and marine acids by salt of amber, though this is denied by Pott. According to Stockar, however, it forms a white precipitate with sugar of lead. This metal precipitated by an alkali, and dissolved in acid of amber, forms long foliated crystals lying upon one another; from the solution of which the lead may be precipitated by alkalies in the form of a grey powder, and by zinc in its metallic state.

12. *Zinc*, in its metallic state, is readily dissolved by the acid of amber; and by a combination with the precipitate formed by fixed alkali, we obtain long, slender, foliated crystals, lying upon one another. The solution lets fall a white precipitate on the addition of fixed alkali; but this is denied by Stockar, who says that volatile alkali produces a red precipitate.

13. *Bismuth.* By means of heat, Stockar obtained a solution of this semimetal in acid of amber, which was decomposed by alkalies. Wenzel obtained, from a precipitate of bismuth prepared by means of fixed alkali, small, slender, foliated, and yellow crystals; which alkalies cannot decompose, though black precipitates are thrown down by lead and zinc.

14. *Regulus of antimony.* Little or none of this semimetal, in its reguline form, is dissolved in the acid of amber; but it attacks the precipitate made with fixed alkali. This solution is very copiously precipitated by liver of sulphur, but not by alkalies.

The combinations of this acid with gold, platina, nickel, arsenic, and manganese, have either been found impracticable, or not yet attempted; all those above described are non-deliquescent, and part with their acid when exposed to the fire. The elective attractions of this acid, according to Bergman, are singular, as it adheres more strongly, not only to terra ponderosa and lime, but to magnesia, than to fixed alkali.

On the origin of salt of amber, Mr Keir remarks, that "it deserves to be considered as a pure and distinct acid. No proofs have been adduced of its being a modification either of the marine or vegetable acids, as Mr Cornette and M. Hermbstadt have supposed. The former, having distilled spirit of salt with oil of lavender, obtained an acid which smelled like salt of amber, but on examination was found to retain the properties of the muriatic acid. He also relates, that, when purifying a considerable quantity of the salt of amber which he had prepared himself, some sea-salt was separated, which in the distillation had arisen along with it. But this observation cannot be justly applied to show any resemblance betwixt these two, any more than the smell in the former case could show an analogy betwixt it and oil of lavender. This mixture of sea-salt with acid of amber, however, may readily explain the mistake of M. Bourdelin already mentioned. M. Westrumb and M. Hermbstadt have both laboured in vain to convert the acid of amber into acids of sugar and tartar by frequent distillations with spirit of nitre; and their want of success confirms the account already given, that the acids of nitre and amber have no action upon each other, farther than that the former is phlogisticated or changed into red fumes, and the latter becomes whiter. Nevertheless, if Mr Scheele's observation of the identity of the acid liquor, which comes over in the distillation of amber with acetous acid, holds good, we shall have the best reason yet given to ascribe the origin of this acid to the vegetable kingdom; and when we consider the very different properties that are assumed by the vegetable acids, which, however, are convertible into one another, no reason can be drawn from the diversity of its properties with those of other vegetable acids, against its having a common origin with them. Indeed the natural history of amber, its similarity to gums and resins, and its involved insects, afford other arguments in favour of the opinion.

1495 On the nature of the acid of amber.

IX. *Acid of Arsenic.*

1496 M. Pelletier's method of procuring the arsenical acid.

M. Berthollet remarks upon Mr Scheele's process, that during the operation a great quantity of dephlogisticated air is expelled from the acid. M. Pelletier has found another method of procuring the arsenical acid. He mixes common white arsenic with nitrous ammoniac, and distils the mixture. At first phlogisticated nitrous acid passes over, then the volatile alkali, and lastly the arsenical acid remains in the retort in form of a vitreous mass, which deliquesces into a very dense acid liquor, reddening syrup of violets, and effervescing with alkalies. Mr Macquer had formerly described this process, and observed, that the nitrous acid passes over first, and then the volatile alkali; but was of opinion that the residuum was nothing but arsenic. He mentions a detonation which took place in his experiment; but nothing of this kind was observed by M. Pelletier: he only informs us, that the nitrous acid was driven over with great violence, while that of arsenic united with the volatile alkali. M. Berthollet, who has endeavoured to ascertain the weight gained by the conversion of sulphur, phosphorus, and arsenic, into acids, determines that of arsenic to be about one-ninth of the whole. At the same time he observes, that this additional weight does not discover the whole weight of the air contained in the

Acid of molybdæna

the arsenic, as it had that necessary to convert it into calx before the operation of converting it into an acid was begun. On the other hand, M. Bergman asserts, that one-fifth of white arsenic is phlogiston, and that this calx is converted into acid merely by being deprived of its phlogiston. Thus the *facts* related by these two celebrated chemists differ enormously from one another; M. Berthollet affirming that the arsenic *gains* a ninth of its original weight in the process of acidification; and M. Bergman, that it *loses* a fifth part of the same. M. Berthollet endeavours to reconcile this, by supposing that Bergman had employed marine acid for the preparation of his arsenical acid, which is well known to cary off with it some part of most of those substances with which it is capable of combining; and to this he attributes the loss of weight in Bergman's process.

IX. *Acid of Molybdæna.*

1497
M. Pelletier's experiments.

The opinion of M. Bergman concerning the metallic nature of the acid of molybdæna has obtained some confirmation from the experiments of M. Pelletier. He was not able indeed to obtain any regulus; but by means of oil alone he procured, by two hours vehement heat, a substance slightly agglutinated with a metallic lustre, containing small round grains of a grey metallic colour, very visible by the help of a magnifier. These he supposes to have been a true regulus of molybdæna; which he found to possess the following properties. 1. It is calcinable by fire into white calx. 2. It detonates with nitre, and the residuum is a calx of molybdæna united with the alkali of the nitre. 3. It is converted into a white calx by means of nitrous acid. 4. It yields inflammable air when treated with alkalies in the dry way, and forms peculiar compounds with them. 4. It forms regenerated molybdæna with sulphur. 6. It unites, and forms peculiar substances with metals. By uniting it with silver, iron, and copper, we have friable reguline masses; and refractory powders with lead and tin.

Our author, in consequence of his experiments, considers molybdæna as a metallic substance mineralized by sulphur; and the earth called the acid of molybdæna as a calx much dephlogisticated, which has retained part of the air contained in the nitrous acid. He observes likewise an analogy betwixt molybdæna and antimony in their chemical results. Both of them yield vitrifiable argentine flowers by similar operations, and both are changed into white earths by nitrous acid; but they differ in the two following respects. 1. The latter easily gives a fusible regulus; but the molybdæna seems to be the most refractory of all the semimetals. 2 The calx of regulus of antimony is soluble by alkalies in the moist way, but that of molybdæna is not.

X. *Acid of Tungsten or Wolfram.*

1498
Properties of tungsten.

Mr Luyart, who has examined this mineral, gives the following account of it. 1. It is infusible by the blow-pipe, though the angles of the pieces into which it is broken are thereby rounded. 2. It effervesces with microcosmic salt, and melts before the blow-pipe into a reddish glass. 3. With borax it effervesces; and by the outward flame of the blow-pipe is changed into a reddish glass; by the internal flame into a greenish one. 4. Heated by itself in a crucible, it swelled, became spongy, semivitrified, and was attracted by the magnet. 5. With an equal part of nitre it detonated, or boiled up with a blue flame round the edges, and nitrous vapours arose. The mass was soluble in water, and let fall a white precipitate with acid. 5. It melted readily with fixed alkali, leaving a kind of black matter in the crucible, and a smaller quantity of lighter coloured substance on the filter. These residuums showed a mixture of iron and manganese. 6. With nitrous acid the filtered solution let fall a white precipitate, at first sweet, but afterwards bitterish and sharp, and which caused a disagreeable sensation in the throat; and the acidity of the solution of it was manifest, by its turning the tincture of turnsole red.

Acid of tungsten.

Having examined the substance by means of liquids in Mr Scheele's way, they obtained the same yellow powder which he had characterized as the acid of tungsten, along with a very small residuum, which appeared to contain a mixture of tin. Proceeding farther in the analysis, they found that wolfram is composed of manganese, calx of iron, the yellow matter called the *acid of tungsten* by Bergman and Scheele, with a very little mixture of quartz and tin, and which they considered as accidental.

1499
Of the yellow matter, called its acid by Mr Scheele.

They now proceeded to examine the yellow matter, supposed by the two celebrated chemists just mentioned to be a simple acid salt, but which turned out very different on their inquiries. In order to procure a quantity of it, they melted six ounces of wolfram with as much vegetable alkali, dissolved the mixture in distilled water, filtrated the liquor, and evaporated it to dryness. Thus they obtained a white salt; upon which, when dry, they poured nitrous acid, and set it to boil in a sand-bath; by which operation it became yellow. They then decanted the liquor, pouring fresh acid upon the residuum; and repeated the operation a third time in order to deprive it of all the alkali. The remaining powder was then calcined in a cupelling furnace under a muffle, when it came out quite pure and yellow. The properties of it were then found to be as follow. 1. It is entirely insipid, and of the specific gravity of 6.12. 2. Before the blow-pipe, it continues yellow in the exterior flame even though put on charcoal; but grows black and swells, though it does not melt, in the internal flame. 3. In the internal flame it forms a blue transparent glass with microcosmic salt. The colour vanishes in the external flame, but appears again in the internal one; but by a continuance of this operation, it at last loses its colour so much that it cannot be recovered. 4. It effervesces, and forms a brownish yellow transparent glass with borax, which keeps its colour in both flames. 6. When triturated with water, it forms an emulsion which passes through filters without becoming clear, and continues a long time without any deposition. 7. It is insoluble in acids, but dissolves readily in the vegetable alkali both in the moist and dry way; though the produce has always an excess of alkali. 8. On adding nitrous acid in greater quantity than what is necessary to saturate this excess, a white powder falls, which is the same with the acid of tungsten discovered by Mr Scheele; but which Messrs Luyarts will not

Acid of tungsten.

1500 No simple acid procurable from tungsten.

not allow to be a simple acid, though they admit that it contains one; and affirm, that its properties are various according to the circumstances of its precipitation. The properties of it, as described by them, are the following. 1. It is fusible before the blow-pipe, exhibiting the same phenomena as the yellow matter. 2. By calcination in a little pot or test, it emits the smell of nitrous acid, and turns yellow; but, on cooling, remains white, insipid, and insoluble; and this residuum melts by itself before the blow-pipe. 3. A yellow colour is produced either by vitriolic or marine acids; and the filtrated liquor affords a neutral salt with basis of fixed alkali, according to the nature of the acid employed. If the vitriolic acid is employed, and the operation performed in a retort, a quantity of nitrous acid passes over. 4. If, instead of pouring the acid on the salt, it be poured upon its solution, no precipitate will be formed, not even by making the liquor boil, if the quantity of acid is small; only the solution loses its sweet taste, and acquires more bitterness. On pouring on a large quantity of acid, and causing the liquor boil, a yellow precipitate is formed in every respect similar to the yellow matter so often mentioned. 5. This salt is completely dissolved by the boiling with vinegar. On leaving the solution to cool, a white waxy matter adheres to the sides of the vessel; which being washed and kneaded with the fingers, forms an adhesive mass like bird-lime, having a fat and greasy taste. By exposure to the air it acquires a dark grey colour, loses its adhesive property, and becomes bitter. It dissolves in water; and gives at first a sweet, then a bitter taste, making the tincture of turnsole red. 6. On evaporating the alkaline solution to dryness, pouring acetous acid upon the residuum, and then making it boil, the greater part of the residuum, was dissolved, and on cooling afforded feathery crystals. These when edulcorated had a sweet taste, though less strong than that of the former salt, which afterwards became bitter. Their solution turned blue paper red; was precipitated, and became like an emulsion with spirit of wine; and the residuum, which did not dissolve, appeared to be of the same nature. The crystals dissolved in fresh acetous acid, and communicated a blue colour to the acid; but this gradually disappeared on cooling, and a glutinous matter was deposited on the sides of the vessel, which had the properties of the former substance of that sort. If, in place of letting the solution cool, it should be kept boiling, the blue colour disappears, and nothing is precipitated. By adding spirit of wine when the liquor is almost evaporated to dryness, a white powder is precipitated; which after being edulcorated with fresh spirit of wine, tastes exceedingly bitter, and is very soluble in water. This solution, however, does not redden blue paper, nor make a blue with vinegar. With vitriolic acid its solution is blue; with vitriol of copper it forms a white precipitate. All these salts, by calcination, first become blue, then yellow, and lastly white. 7. On pouring a quantity of lime-water upon the solution of the precipitate formed by the nitrous acid, as well as on those obtained by the acetous acid, white precipitates were formed, all of which were a true regenerated tungsten. Having afterwards impregnated the liquors with fixed air, and boiled them in order to precipitate the lime more completely, they found in the solutions, after they were filtrated and evaporated to dryness, neutral salts formed of the precipitating acids, joined with alkaline and calcareous bases. This proved, that both alkali and acid were concerned in the precipitation. 8. On pouring the vitriolic solutions of iron, copper, and zinc, as well as that of marine mercurial salt, alum, and Prussian alkali, upon the solution of the precipitate formed by the nitrous acid, no precipitation ensues, and the acetous salts of copper and lead give white precipitates; but the Prussian alkali forms no precipitate with the acetous salts. Hence it appears that this salt is not a simple acid, but rather a salt composed of the yellow matter, fixed alkali, and the precipitating acid; and its composition appears more fully from the following experiments with the volatile alkali.

1. The yellow powder dissolves entirely in volatile alkali, but without any perfect saturation taking place; and the alkali always prevails. 2. The solution being set in a sand-bath, produced needle-like crystals, which had a sharp bitter taste, exciting a disagreeable sensation in the throat. Their solution turned the tincture of turnsole red, and the liquor from which they were crystallized had the same properties. 3. Having repeated this operation with different quantities of the same crystals, leaving some longer on the fire than others, solutions were obtained, whose acidity was in proportion to the time they had remained on the fire; but during the operation they all emitted the smell of volatile alkali. By calcination this alkali was entirely dissipated, and the residuum was a yellow powder, perfectly similar to that with which the operation was begun. On making use of a retort for the operation, the remaining powder was blue. 4. This salt precipitates the vitriolic salts of iron, copper, zinc, and alum, calcareous nitre, marine mercurial salt; the acetous salts of lead and copper; and with lime-water regenerates tungsten. The vitriolic acid decompounds it, and forms a blue precipitate; the nitrous and marine acids produce a yellow; but no precipitate is occasioned by the Prussian alkali.

Having poured nitrous acid upon a portion of the solution with excess of alkali, a white powder was precipitated, which, after edulcoration, had a taste at first sweet, but afterwards sharp and bitter, and its solution turned the tincture of turnsole red. This, on examination, appeared to be a triple salt formed of the yellow powder, volatile alkali, and the precipitating acid.

1501 A kind of semimetal procurable from tungsten.

The following experiments realize the conjecture of Bergman, that the acid of tungsten is the basis of a particular semimetal.

1. "Having kept 100 grains of the yellow powder (says M. Luyart) in a Zamora crucible well covered, and set the whole in a strong fire for half an hour, it became a spongy mass of a bluish black colour, the surface of which was crystallized into fine points, like plumose antimony, and the inside compact, and of the same colour. It was too hard to be broken in pieces by the fingers; and, when ground, was reduced to a dark blue colour.

2. "Having mixed 100 grains of the same powder with 100 of sulphur, and put the mixture in a Zamora crucible on a strong fire for a quarter of an hour, it came out a dark-blue mass, which was easily broke by

Acid of tungften.

the fingers, and the infide prefented a cryftallization like needles as the laft, but tranfparent, and of the colour of a dark lapis lazuli. This mafs weighed 42 grains, and when placed on burning coals yielded no fmell of fulphur.

3. " Having put another 100 grains of this powder into a Zamora crucible, provided with charcoal, and well covered, and placed it in a ftrong fire, where it remained an hour and a half, we found, on breaking the crucible after it was cool (A), a button, which fell to powder between the fingers. Its colour was dark brown; and on examining it with a glafs, there was feen a congeries of metallic globules, among which fome were the bignefs of a pin's head, and when broke had a metallic appearance at the fracture in colour like fteel. It weighed 60 grains: of courfe there was a diminution of 49. Its fpecific gravity was 17.6. Having calcined part of it, it became yellow, with $\frac{24}{100}$ increafe of weight. Having put one portion of this fubftance powdered, in digeftion with the vitriolic acid, and another with the marine acid, neither of them fuffered more diminution than $\frac{1}{160}$ of their weight; then decanting the liquor, and examining the powder with a glafs, the grains were ftill perceived of a metallic afpect. Both the acid liquors gave a blue precipitate with the Pruffian alkali, which let us know that the fmall diminution proceeded from a portion of iron which the button had undoubtedly got from the powder of the charcoal in which it had been fet. The nitrous acid, and aqua-regia extracted likewife from two other portions the ferruginous part; but befides, they converted them into yellow powder, perfectly fimilar to that which he ufed in this operation.

4. " Having put 100 grains of gold and fifty of the yellow powder in a Zamora crucible furnifhed with charcoal, and kept in a ftrong fire for three quarters of an hour, there came out a yellow button which crumbled in pieces between the fingers; the infide of which fhowed grains of gold, feparated from others of a dark-brown colour. This demonftrated there had not been a perfect fufion and likewife that this fubftance was more refractory with gold, fince the heat which it endured was more than fufficient to have melted it. The button weighed 139 grains; of courfe there was a diminution of 11 grains. Having put this button with lead in the cupelling furnace, the gold remained pure in the cupel; but this operation was attended with confiderable difficulty.

5. " Having made a mixture of platina and yellow powder in the preceding proportions, and expofed it to a ftrong fire, with the fame circumftances, for an hour and a quarter, it produced a button which crumbled with eafe between the fingers, and in which the grains of platina were obferved to be more white than ufual, and fome of them changed fenfibly in their figure. This button weighed 140 grains, and of confequence there had been a lofs of 10 grains. When calcined, it took a yellow colour, with very little increafe of weight; and after wafhing it to feparate the platina, there remained 118 grains of a black colour. Having placed this portion again to calcine over a ftrong fire in a muffle, it fuffered no fenfible alteration in weight or colour; for it neither grew yellow, nor took the brown colour of the platina, but kept the fame blacknefs as before it was calcined. It muft be attended to, that in the wafhings there was not fo much care taken to collect all the platina as to deprive it of the yellow colour, and for this reafon the water carried off part of the fine black powder: and confequently the increafe which the platina preferved, after being wafhed and calcined the fecond time, ought to be computed more than the 18 grains which it fhowed by its weight.

" Having mixed the yellow powder with other metals in the preceding proportions, and treated them in the fame manner, the refult was as follows:

6. " With filver it formed a button of a whitifh-brown colour, fomething fpongy, which with a few ftrokes of a hammer extended itfelf eafily, but on continuing them fplit in pieces. This button weighed 142 grains, and is the moft perfect mixture we have obtained, except that with iron.

7. " With copper it gave a button of a copperifh red, which approached to a dark brown, was fpongy, and pretty ductile, and weighed 133 grains.

8. " With crude or caft-iron, of a white quality, it gives a perfect button, the fracture of which was compact, and of a whitifh brown colour: it was hard, harfh, and weighed 137 grains.

9. " With lead it formed a button of a dull dark-brown, with very little luftre; fpongy, very ductile, and fplitting into leaves when hammered: it weighed 127 grains.

10. " The button formed with tin was of a lighter brown than the laft, very fpongy, fomewhat ductile, and weighed 138 grains.

11. " That with antimony was of a dark-brown colour, fhining, fomething fpongy, harfh, and broke in pieces eafily: it weighed 108 grains.

12. " That of bifmuth prefented a fracture, which, when feen in one light, was of a dark-brown colour, with the luftre of a metal; and in another appeared like earth, without any luftre: but in both cafes one could diftinguifh an infinity of little holes over the whole mafs. This button was pretty hard, harfh, and weighed 68 grains.

13. " With manganefe it gave a button of a dark bluifh-brown colour and earthy afpect; and on examining the internal part of it with a lens, it refembled impure drops of iron: it weighed 107 grains."

XI. *Acid of Ants.*

Etmuller is among the firft authors who mentions the exiftence of this acid, and fpeaks of obtaining it by diftillation. Nothing of its properties, however, was known, until Margraaf undertook to examine it; of whofe experiments we have an account in the Memoirs of the Berlin Academy for 1749. Since his time a number of chemifts have profecuted the fubject to

(A) " The firft time we made this experiment, we broke the crucible without letting it cool entirely; and as foon as the matter was in contact with the air, it took fire, and its dark brown colour turned inftantly yellow."

Acid of ants.

to a considerably greater length; but Mr Keir prefers the researches of Arvidson, Bucholtz, and Hermbstadt, to the rest.

The acid in question is a natural juice which the insects discharge when irritated, and which is very pungent to the smell as well as taste. Thus it may instantly be perceived on turning up an ant-hill in spring or summer. The *formicæ rubræ* of Linnæus are those insects which have hitherto supplied this acid. Mr Arvidson advises to collect them in the months of June and July, by laying some smooth sticks upon an ant-hill; which being then disturbed, the ants will run upon the sticks in great numbers, and may then be swept off into a vessel containing water until it be full. Hermbstadt collects them in the same manner, but into a dry bottle, to avoid the evaporation of the superfluous liquid. Bucholtz having moistened the inside of a narrow necked glass bottle with honey and water, sunk it into a disturbed ant-hill until the mouth was level with the ground; on which the insects, allured by the smell of the honey, went into the bottle, and could not get out.

1502 Different methods of obtaining this acid.

For obtaining the acid, Margraaf employed distillation, with the addition of fresh water. Thus he obtained, from 24 ounces of fresh ants, 11 ounces and two drachms of acid, some volatile alkali, empyreumatic oil, and a residuum containing earth and fixed salt. Arvidson made use of two methods: One consisted in distilling the ants when dry; from a pound of which, in this state, he obtained eight ounces of acid besides the empyreumatic oil. His other method was to inclose, in a piece of linen, the ants previously cleaned by washing in water, then to pour boiling water upon them, and to repeat the operation until it could extract no more acid; which is then obtained by squeezing the linen, mixing all the liquors, and filtering them. Thus from a pound of ants he obtained a quart of acid liquor, which tasted like vinegar, but was specifically heavier. By distillation Hermbstadt obtained from a pound of dry ants ten ounces and a half of yellow empyreumatic liquor, which did not taste more strongly acid than the spirit obtained by distilling wood, on which swam three drachms of a brown fetid oil, in all respects like that of hartshorn. In the retort was left a black residuum weighing one ounce six drachms, which exhibited signs of containing volatile alkali. By distilling a pound of ants with three of water, according to Mr Margraaf's method, he obtained an acid liquor and some oil in the receiver; and from the surface of that which remained undistilled, he collected a drachm and an half of fat oil.

The specific gravity of the acid liquor obtained by Mr Arvidson's maceration was 1,0011; that of the same liquor, when distilled, 1.0075; and of the acid concentrated by freezing, 1.0453. According to Bucholtz, the acid liquor thus obtained by maceration did not grow in the least mouldy in the space of four weeks; during which it was allowed to rest in order to free itself perfectly from the impurities it contained. Mr Hermbstadt, however, prefers Margraaf's method of distillation to that of Arvidson's macerations, not only as being a more perfect analysis, but as less laborious; though he finds fault also with Margraaf's method, as diluting the acid too much, and altering it so that it has not the smell of living ants. He totally disapproves of the method of distilling dried ants, as the acid is thus in a great measure decomposed, and the remainder united with much oil. To avoid all these inconveniences, he contrived another method, namely, to express the juice of the insects; by which means he obtained at once a concentrated liquor fit for distillation. In this way he obtained from two pounds of dried ants 21 ounces and two drachms of juice, which had a pungent and highly acid smell, resembling the vapours of fluor acid; in taste resembling concentrated vinegar and acid of tartar; to which last it might be compared for strength of acidity. By distilling eight ounces of this expressed liquor, he obtained six ounces and a half of clear acid, equal in strength to a very concentrated vinegar.

1503 Properties of the pure acid.

The acid, when thus procured in purity, has a pungent, not unpleasant smell, a sharp, caustic taste, and an agreeable acidity. It reddens blue paper, syrup of violets, and litmus; blackens the vitriolic acid, and converts part of it into a sulphureous vapour. It is also decomposed by distillation with nitrous acid. Spirit of salt likewise, when dephlogisticated, decomposes it, but not in its ordinary state. It does not form sulphur by an union with phlogiston, but produces inflammable vapours by dissolving iron or zinc. By the assistance of a gentle heat it dissolves soot, but oils with much more difficulty, and powder of charcoal not at all. It does not unite with vitriolic ether; but in distilling a mixture of this acid with spirit of wine, Mr Arvidson saw some traces of an ether, and M. Bucholtz perfectly succeeded in making an ether by means of it. It unites with fixed alkali, forming, according to M. Margraaf, a neutral salt, consisting of oblong deliquescent crystals, from which very little acid could be procured by distillation *per se*, but on adding concentrated oil of vitriol, a very strong and pure acid was obtained; from a mixture of which with spirit of wine, M. Bucholtz readily obtained a true ether. With mineral alkali it forms deliquescent foliated crystals of a saline bitter taste, and soluble in twice their weight of water. With volatile alkali it forms an ammoniacal liquor; which, according to Arvidson, cannot be brought into a dry state; but Mr Arvidson says he has obtained crystals from it, though very thin and deliquescent. Margraaf obtained dry crystals by uniting this acid, with chalk or coral; and Arvidson observes that this salt is transparent, cubical, or rhomboidal, nondeliquescent, soluble in eight parts of water, of a bitter taste, and insoluble in spirit of wine. No acid can be obtained from it by distillation *per se*. From a solution of magnesia in this acid, Mr Arvidson obtained some saline particles by deposition, and afterwards an efflorescence of transparent salt rising round a saline mass. This salt had scarcely any taste, was soluble in 13 parts of water, and insoluble in spirit of wine. With ponderous earth the acid formed a cluster of bitter needle-like crystals, which did not deliquesce, were soluble in four times their quantity of water, insoluble in spirit of wine, and when burnt gave out a smell like that of burnt sugar, leaving a coal which effervesced with acid. It unites with difficulty to the earth of alum, and can scarcely be saturated with it. It does not precipitate silver, lead, or mercury, from their solution in nitrous acid; whence it seems to have no affinity to the marine

Acid of apples.

rine acid: and as it does not precipitate lime from the marine acid, it seems to have as little with the vitriolic. From his experiments, however, Margraaf concluded,
1504 Has an affinity with the acetous acid. that the acid of ants, in many respects, though not in all, has a great affinity with the acetous acid. From this it is distinguished by forming different compounds, and likewise by having different affinities. It dislodges the acetous acid also in all instances, and the arsenical acid from cobalt and nickel. It has a greater attraction for fixed alkalies than for lime.

1505 Its effects on metals. As a solvent it acts but weakly upon copper; not at all, or very little, on silver, lead, tin, regulus of antimony, or bismuth, but strongly on iron or zinc. It dissolves, however, the calces of copper, silver, zinc, and lead, without affecting those of tin, regulus of antimony, or bismuth. The calx of quicksilver, according to Margraaf, is revived by it. According to Arvidson, it crystallizes with iron, zinc, or lead; does not act upon the regulus of antimony, of arsenic, cobalt, or nickel; though it dissolves their calces as well as the precipitate of manganese. Gold, mercury, and the calx of platina, are not affected by it; but it crystallizes with those of copper, silver, lead, bismuth, and mercury.

1506 Acid procured from various insects. In its strength of attraction, the acid of ants exceeds those of vinegar, borax, and the volatile sulphureous and nitrous acids. Insects armed with stings, as bees, wasps, and hornets, are likewise said to discharge a very acid juice when irritated; and Mr Bonnet has observed a very strong acid ejected by a caterpillar which he distinguishes by the name of *grande chenille du saule a queu fourchue*. None of these, however, have been as yet particularly examined.

XII. *Acid of Apples.*

That the juices of unripe fruits contain some kind of acid has been universally known, and attempts to investigate the nature of it have been made some time ago: but it is to Mr Scheele that we owe the disco-
1507 Acid of citrons how procured. very of the particular acid now treated of. He had observed that the juice of citrons contained a particular acid; which, by being united with lime, formed a salt very insoluble in water; and which therefore by means of lime could be readily separated from the mucilaginous part of the juice. By adding vitriolic acid to this compound of lime with the acid juice, almost in the same manner in which he used to procure the acid of tartar, the lime was again separated, and the pure acid of citrons obtained. Proceeding in the same manner with other fruit, he found that an acid, agreeing in every respect with that of citrons, could be procured from the juice of the *ribes grossularia*. Examining the juice which remained after the separation of the former acid from the citrons, he found that it still contained another acid; which being saturated with more calcareous earth, formed a salt
1508 Another acid procured from the juice of fruits. easily soluble in water, and therefore remained suspended in the juice. To separate this new salt, he added some spirit of wine, by which the salt was precipitated; but finding that it still contained much gummy matter, he judged that it would be proper to attempt a separation of this gum before he precipitated the salt. For this purpose he evaporated some of the juice of the ribes grossularia to the consistence of honey, dissolving the mass afterwards in spirit of wine. Thus the acids, which are soluble in the spirit, were easily separated by filtration from the insoluble gum. He then evaporated the spirit, adding to the remainder twice its quantity of water, with as much chalk as was necessary for the saturation. The liquor was next boiled for two minutes; during which the insoluble salt was precipitated, and the liquor separated from it by filtration contained the solution of chalk in the new acid. To this solution he added spirit of wine, which again precipitated the salt, while some saponaceous and saccharine matters remained dissolved in the spirit. 1509

Its properties. Having thus at last obtained the salt in a state of purity, he proceeded to examine its nature; and found, 1. That some of it, spread on his nail, soon dried, and assumed the appearance of varnish. 2. It was very soluble in water, and turned litmus red. 3. When the solution had stood some days exposed to air, it was found to have deposited a number of small crystals, which could only be dissolved by a quantity of boiling water; and this salt was also found to be completely neutralized, so that, it yielded its calcareous earth to a fixed alkali. 4. The salt was decomposed by heating *per se* in a crucible, and left a mild calcareous earth. 5. The acid was separated from the earth by adding oil of vitriol diluted with water until gypsum was no longer precipitated, and the new acid was left disengaged, so that it could be separated by filtration. 6. By this operation, however, all the lime was not precipitated; so that the separation of the acid was not complete. 7. He observed that the acid had a greater attraction for lead than for lime; and therefore made use of the method he had formerly discovered for separating the acid of sorrel. To the acid he added a solution of sugar of lead; by which the acid was precipitated along with the lead, and the vinegar was left 1510
in the liquor. To this precipitate, cleaned from How procured in
the acetous acid by filtration, he added vitriolic acid, perfect purity.
which expelled the weaker vegetable one, and thus left it quite pure and free from any heterogeneous mixture.

The juice of apples, either ripe or unripe, was found to contain no acid of citrons, but a large quantity of the new acid; which, being thus alone, he could more easily procure by a single operation. The best method of procuring this he found to be by saturating the juice of the apples with a solution of fixed vegetable alkali, and pouring a solution of sugar of lead to that of the salt just mentioned. The effect of this was a double decomposition, and a precipitate of lead combined with the new acid. To the edulcorated precipitate he then added a dilute vitriolic acid till he could no longer perceive any sweet taste in the liquor; for the first portions of the vitriolic acid dissolve a part of the calx of lead, and impart a sweetish taste to the liquor, which is sensible, notwithstanding its acidity; but when the quantity of vitriolic acid is sufficient to saturate the whole of the calx, all the metal falls to the bottom, and the sweetness ceases; so that the acid is at once obtained pure. 1511

Properties of it when obtained from the juice of apples. The acid of apples is possessed of the following properties. 1. It cannot be crystallized, but always remains in a liquid state; or, if much evaporated, attracts the moisture of the air. 2. With fixed alkalies

Acid of apples.

of all kinds it forms deliqueſcent ſalts. 3. With calcareous earth it forms ſmall irregularly ſhaped cryſtals, which cannot be diſſolved but in a large quantity of boiling water; but if the acid is ſuperabundant, the ſalt readily diſſolves in lime-water. 4. It is effected by ponderous earth in the ſame manner as by lime. 5. Earth of alum forms, with the acid of apples, a ſalt not very ſoluble in water. 6. With magneſia the acid forms a deliqueſcent ſalt. 7. Iron is diſſolved into a brown liquor, which does not cryſtallize. 8. The ſolution of zinc affords fine cryſtals. 9. On other metals it has no remarkable effects. From the acid of citrons it differs. 1. The acid of citrons ſhoots into fine cryſtals. 2. The acid of apples can be eaſily converted into that of ſugar, which Mr Scheele could not accompliſh with that of citrons; though Mr Weſtrumb has ſince done it. 3. The ſalt formed with the citron acid and lime is almoſt inſoluble in water; but that with acid of apples and lime is eaſily ſoluble. 4. Acid of apples precipitates mercury, lead, and ſilver from their ſolution in nitrous acid, and likewiſe the ſolution of gold, when diluted with water; but the acid of citrons does not alter any of theſe ſolutions. 5. The acid of citrons ſeem to have a greater attraction for lime than that of apples.

1512 Produced from ſugar by means of nitrous acid.

It is remarkable that this acid is the firſt produced in the proceſs for making ſugar. If a diluted acid of nitre be drawn off from a quantity of ſugar until the mixture becomes a little brown, which is a ſign that all the nitrous acid is evaporated, the ſyrup will be found to have acquired a ſouriſh taſte; and if, by means of lime, we next ſeparate all the acid of ſugar, another will ſtill remain, which diſſolves the calcareous earth. When this acid is ſaturated with chalk, and the ſolution filtered and mixed with ſpirit of wine, a coagulation takes place. On ſeparating the curdled part by means of a ſieve, diſſolving it in water, and then adding ſome vinegar of lead, the calx of lead will be precipitated; and if the new acid is then ſeparated from the metal by means of diluted oil of vitriol, it will be found to poſſeſs all the properties of the acid of apples, and is indeed the ſame. The ſpirit of wine, which has been employed to precipitate the calcareous ſalt, leaves on evaporation a reſiduum of a bitter taſte, very deliqueſcent, and ſimilar to the ſaponaceous extract of the citron.

1513 Experiments with nitrous acid on various ſubſtances.

The following are the reſults of Mr Scheele's experiments with the nitrous acid upon different ſubſtances. 1. From gum arabic he obtained both the acid of apples and of ſugar. 2. The ſame products were obtained from manna. 3. From ſugar of milk he obtained not only its own peculiar acid, but thoſe of apples and ſugar. 4. Gum tragacanth, during its ſolution in nitrous acids, lets fall a white powder, which was found to be the acid of the ſugar of milk. This gum contained alſo the acid of apples and of ſugar, and a ſalt formed from lime and the acid of apples. 5. Starch left an undiſſolved matter; which being ſeparated by filtration, and waſhed, reſembled a thick oil like tallow, which, however, was found to be very ſoluble in ſpirit of wine. By diſtillation he obtained from this oily matter an acid ſimilar to that of vinegar, and an oil which has the ſmell of tallow, and congeals by cold; and, beſides theſe ſubſtances, he found that ſtarch yielded the acids of apples and ſugar. 6. From the root of ſalep he obtained the acid of apples, with a large quantity of calcareous ſaccharine ſalt. 7. Extract of aloes indicated the exiſtence of the acids of ſugar and apples, and loſt the greateſt part of its bitter taſte. During the digeſtion a reſinous matter was ſeparated, which ſmelled like flowers of benzoin, and took fire on being heated in a retort. 8. Extract of colocynth was converted by nitrous acid into a reſinous ſubſtance, and ſhowed ſome ſigns of containing acid of ſugar. 9. The extracts of Peruvian bark and of the other plants examined by Mr Scheele, gave both the acids of apples and ſugar. 10. Theſe two acids were likewiſe obtained from an infuſion of roaſted coffee, evaporated to the conſiſtence of a ſyrup. 11. The ſame products were obtained from an extract of rhubarb, which yielded alſo a reſinous matter. 12. Juice of poppies afforded the ſame reſults. 13. Extract of galls did the ſame. 14. The eſſential oils afforded little or none of the acids; but the oil of parſley-ſeeds ſeemed to be entirely convertible into them. 15. With a very concentrated acid he was able alſo to decompoſe animal ſubſtances. From glue he thus obtained fine cryſtals of acid of ſugar, and afterwards acid of apples. Iſinglaſs, whites and yolks of eggs, afforded the ſame products. From all theſe ſubſtances, eſpecially the laſt, a fat matter was ſeparated: but it was remarkable that the gas, expelled during the proceſs, was compoſed of a little fixed air, a great quantity of phlogiſticated air, and very little nitrous air, whereas no phlogiſticated air is obtained in the uſual proceſs for preparing acid of ſugar. He obſerved alſo that in the proceſs for this acid, a ſmall quantity of vinegar is found in the receiver. He could not obtain the acid of ſugar from the ſaponaceous extract of urine; but got inſtead of it a ſalt, which, when completely purified, reſembled exactly the flowers of benzoin. The ſame ſalt is precipitated in abundance by adding to the extract of urine a little vitriolic or marine acid; and Mr Scheele had already remarked that the ſame ſalt is obtained in the diſtillation of ſugar of milk.

1514 Of the nature of this acid.

From the various experiments which have been made on this acid, it ſeems, according to Mr Keir, to be in an intermediate ſtate betwixt acid of tartar and acid of ſugar. This, however, ought not to prevent it from being accounted a ſeparate and diſtinct acid, otherwiſe we might confound all the vegetable acids with one another. It approaches more nearly to the nature of acid of milk than of any other. From this alſo, however, it is diſtinguiſhed, becauſe the ſalt formed by the union of acid of milk with lime is ſoluble in ſpirit of wine, but not that from lime and the acid of apples. According to Mr Hermbſtadt, if three parts of ſmoking nitrous acid be abſtracted from one part of ſugar, and if the brown acid maſs which remains in the retort be diluted with ſix times its weight of diſtilled water, and ſaturated with chalk, two compounds will be formed; one conſiſting of the acids of tartar and lime, which will precipitate; and the other of lime and the acid of apples, which will remain ſuſpended. If the calcareous earth be precipitated from this latter ſolution by adding acid of ſugar, a pure acid of apples will be left in the liquor: and

Acetous acid.

and he farther informs us, that this acid of apples may be changed entirely into thoſe of ſugar and vinegar, by means of ſtrong nitrous acid.

XIII. *Acetous Acid.*

1515 How to cryſtallize ſpiritus Mindereri.

It is generally believed, that the combination of this acid with volatile alkali is altogether incapable of cryſtallization; but Scheffer and Morveau inform us, that it may be reduced into ſmall needle-ſhaped cryſtals, when the ſpiritus Mindereri is evaporated to the conſiſtence of a ſyrup, and left expoſed to the cold. The ſalt has a very ſharp and burning taſte, but a conſiderable quantity is loſt during the evaporation. Weſtendorf, by adding his concentrated vinegar to volatile alkali, obtained a tranſparent liquor which did not cryſtallize. By diſtillation it went over intirely into the receiver, leaving a white ſpot on the retort. A ſaline tranſparent maſs, however, appeared in the receiver under the clear fluid. On ſeparating it from the liquid, and expoſing it to a gentle heat, it melted, threw out white vapours, and in a few minutes ſhot into ſharp cryſtals reſembling nitre. Theſe remained unchanged in the cold; but when melted with a gentle warmth, ſmoked and evaporated. Their taſte was firſt ſharp and then ſweet.

1516 Salt from the acetous acid combined with calcareous earth.

The ſalt formed by uniting acetous acid with calcareous earth has a ſharp bitter taſte, and ſhoots into cryſtals ſomewhat reſembling ears of corn. Theſe do not deliquate in the air, unleſs the acid has been ſuperabundant. They are decompoſed by diſtillation *per ſe*, the acid coming over in white inflammable vapours ſmelling like acetous ether, ſomewhat empyreumatic, and condenſing into a reddiſh brown liquor. By rectification this liquor becomes very volatile and inflammable; on adding water, it acquires a milky appearance, and drops of oil ſeem to ſwim upon the ſurface; a reddiſh brown liquor, with a thick black oil, remain after rectification in the retort. On mixing this calcareous ſalt with that of Glauber, a double decompoſition takes place; we have a gypſum and the mineral alkali combined with acetous acid. By calcination, the mineral alkali may be obtained from this ſalt in a ſtate of purity. This acetous calcareous ſalt is not ſoluble in ſpirit of wine.

1517 With magneſia.

On ſaturating this acid with magneſia, and evaporating the liquor, we obtain a viſcid ſaline maſs like mucilage of gum arabic, which does not ſhoot into cryſtals, but deliqueſces in the air. It has a ſweetiſh taſte at firſt, but is afterwards bitter. It is ſoluble in ſpirit of wine, and parts with its acid by diſtillation without addition.

1518 With zinc.

Acetous acid diſſolves zinc both in its metallic and calciform ſtate, and even when mixed with other metals. By concentrated vinegar the zinc is diſſolved with great heat, ſulphureous ſmell, and exhalation of inflammable matter. By this union we obtain a congealed maſs, which on dilution with water ſhoots into oblong ſharp cryſtals at the firſt cryſtallization, and afterwards into cryſtals of a ſtellated form. From this liquor indeed cryſtals of various forms have been obtained by different chemiſts. Monnet obtained from it a pearl-coloured ſalt in friable talky cryſtals; which when thrown on the coals, fulminated a little at firſt, and gave a bluiſh flame, and then melted, letting its acid eſcape, while a yellow calx remained. Hellot informs us, that this ſalt by diſtillation *per ſe* in water, affords an inflammable liquor, and an oil at firſt yellow and then green, with white flowers burning with a blue flame. Weſtendorf obtained no oil in this diſtillation, but ſome acetous acid; a ſweet-taſted empyreumatic liquor impregnated with zinc; ſweet flowers, or ſublimate, ſoluble in water, and burning with a green flame. On applying a ſtronger heat, the zinc was ſublimed in its metallic form, leaving a ſpongy coal at the bottom of the retort. The ſolution gives a green colour to ſyrup of violets, lets fall a white precipitate on the addition of alkalies or an infuſion of galls. It is not precipitated by common ſalt, vitriolated tartar, vitriolic or marine acids, blue vitriol, or corroſive ſublimate; but forms a red precipitate when added to a ſolution of gold; a white precipitate with ſolution of ſilver; a cryſtalline pearly precipitate with ſolution of mercury; and cryſtalline precipitates with ſolutions of biſmuth and tin. According to Bergman, it is decompoſed by acid of arſenic.

1519 Its phenomena with arſenic.

Though regulus of arſenic is not ſoluble in this acid, its calx may be diſſolved either in common or diſtilled vinegar. M. Cadet obtained a ſmoking liquor by diſtillation from a mixture of white arſenic and terra foliata tartari. This experiment has been repeated by the chemiſts of Dijon, and attended with the following curious circumſtances. "We digeſted (ſay they), in a ſand-bath, five ounces of diſtilled vinegar on white pulverized arſenic; the filtrated liquor was covered, during evaporation, with a white ſaline cruſt. Of this ſubſtance were formed 150 grains; on which fixed alkali appeared to have no effect, and which was at firſt conſidered as pure arſenic. However, a cat, which had ſwallowed 72 grains of it, was only affected with vomitings that day and the next, 1520 Vinegar ſuppoſed to be an antidote againſt arſenic.
and afterwards perfectly recovered. A ſimilar doſe was given to a little dog; but as he ran away, the effect it had upon him could not be diſcovered; but he returned afterwards in good health, and never ſhowed any uneaſineſs: whence it may be concluded, that vinegar is in ſome meaſure an antidote againſt the pernicious qualities of arſenic.

"On rediſſolving this ſaline cruſt in pure water, filtering and mixing it with liquid alkali, an irregularly cryſtallized ſalt was formed in it after a few days ſtanding. By this ſalt a yellow precipitate was thrown down from the nitrous ſolution of ſilver; whereas the ſolution of arſenic and terra foliata tartari threw down a white one.

"Equal parts of terra foliata tartari and arſenic, diſtilled in a retort, gave firſt a ſmall quantity of limpid liquor with a penetrating ſmell of garlic, and which had the property of reddening ſyrup of violets; while ſolution of arſenic in water turns that ſyrup green. The vinegar which now aroſe was not ſaturated when arſenic, but effervesced ſtrongly with fixed alkali, with which it became turbid, but did not let fall any precipitate. On changing the receiver, there came over a reddiſh brown liquor, accompanied with thick vapours, diffuſing an intolerable ſmell, in which that of arſenic could ſcarcely be diſtinguiſhed. On continuing the operation, a black powder ſublimed into the neck of the

Acetous acid.

the retort, together with a little arsenic in its metallic form, and a matter which took fire by a lighted candle like sulphur.

"The red liquor still preserved its property of smoking though cold; diffusing at the same time its peculiar and abominable fetor, from which the apartment could scarcely be freed in several days. This liquor does not alter the colour of syrup of violets, but effervesces slightly with fixed alkali, letting fall at the same time a yellow precipitate, which, however, disappeared on an attempt to separate it by filtration.

1521 Curious phosphoric liquor. "M. Cadet had observed, that the smoking liquor of arsenic did not kindle at the approach of a lighted candle; but that, on pouring it from the receiver into another vessel, it had kindled the fat lute with which the junctures had been closed, and which had been dried during the operation: but we, being desirous of examining more fully the nature of the red liquor which collects at the bottom, and has the appearance of oil, having decanted that which swims on the top, and poured the remainder on a filter of paper, before many drops had passed, there arose a thick smoke forming a column from the vessel to the ceiling; a slight ebullition was perceived at the sides of the vessel, and a beautiful rose-coloured flame appeared for a few moments. The paper filter was burnt at one side, but most of it was only blackened. After the flame was extinguished, a fat reddish matter remained: which being melted on burning coals, swelled considerably, emitting a white flame. It then sunk, and left on the coal a black spot, which could not be effaced but by the most vehement fire.

"At the time these observations were made, the liquor had been distilled for three weeks, and the bottle frequently opened. The inflammability could not proceed from the concentration of the vinegar: for the rose-colour of the flame, the precipitation of the sublimate, and the fixity of the spot remaining on the coal, evidently showed that the two substances were in a state of combination; which is also further evinced by the loss of the inflammable property when the liquor was decomposed by fixed alkali.—The smell of the liquor, however, though so intolerably fetid, was attended with no other inconvenience than a disagreeable sensation in the throat, which further strengthens the suspicion that vinegar is an antidote against arsenic.

"The saline brown mass remaining in the retort was partly dissolved by hot water; and the filtrated lixivium was very limpid, but emitted the peculiar smell of the phosphoric liquor. By evaporation it yielded a salt which did not deliquesce in the air, of an irregular shape; and which being put on burning coals, did not smell sensibly of arsenic; lost its water of crystallization; and became mealy and white without being dissipated by heat. On exposing the residuum to the air, it was found next day resolved into a liquor; whence it is probable that most of it was composed of crystallized alkali, having received from the decomposition of the vinegar as much fixed air as was necessary for its crystallization."

1522 Effect of the acetous acid on mercury. This acid does not act upon mercury in its metallic state, but dissolves the mercurial calces, as red precipitate, turbith mineral, and the precipitate formed by adding fixed alkali to a solution of mercury in nitrous acid; with all which it forms white, shining, scaly crystals, like those of sedative salt.

1523 On silver. Vinegar does not act upon silver in its metallic state, but readily dissolves the yellow calces precipitated from its solution in nitrous acid by microcosmic salt and volatile alkali. By the help of a boiling heat also it very copiously dissolves the precipitate obtained by means of a fixed alkali. The last mentioned solution yields shining, oblong, needle-shaped, crystals, which are changed to a calx by means of several acids, especially the muriatic. The silver is thrown down in its metalic form by zinc, iron, tin, copper, and quicksilver.

1524 On gold. Though the acetous acid has no effect upon gold in its metallic state, yet a solution of this metal is decomposed by crude vinegar, which produces both a metallic precipitate and dark violet-coloured powder. Distilled vinegar throws down the gold in its metallic form. The precipitate by fixed alkali digested with acetous acid is of a purple colour. This, as well as fulminating gold, is dissolved by Westendorff's concentrated vinegar; the fulminating gold very easily. The solution is of a yellow colour; and with volatile alkali affords a yellow precipitate; with lixivium sanguinis, a blue one; both of which fulminate. The dry salt of gold dissolves in the acetous acid, and produces oblong yellow crystals.

1525 On inflammable substances. This acid has no effect on fat oils, farther than that when distilled together, some mixture takes place, as the Abbé Rozier has observed. Neither does distilled vinegar act upon essential oils, though M. Westendorff's distilled vinegar dissolved about a sixth part of oil of rosemary, and about half its weight of camphor. The latter solution was inflammable, and let fall the camphor on the addition of water. The acid dissolves all the true gums, and some of those called gum-resins, after being long digested with them. By long boiling, Boerhaave observes, that it dissolves the bones, cartilages, flesh, and ligaments of animals.

1526 Concentration of the acetous acid. The concentration of this acid may be effected by combining it with alkalies, earths, and metals. By combining it with copper, and then crystallizing and distilling the compound, we obtain the acid in the highest state of concentration in which it is usually met with. To produce this strong acid, we have only to distill verdegris, or rather its crystals in a retort. The operation must be begun by a very gentle fire, which brings over an aqueous liquor. This is to be set aside, in order to procure the more concentrated acid, which comes over with a stronger fire. On changing the receiver, and augmenting the heat, we obtain a very strong acid which comes over partly in drops, and partly in white vapours. It is called radical vinegar, or sometimes spirit of Venus, and has a very pungent smell, almost as suffocating as that of volatile sulphureous acid. As the last portions of it adhere pretty strongly to the metal, we are obliged to raise the heat to such a degree as to make the retort quite red in order perfectly to separate them. Hence some part of the metal is raised along with the acid, which, dissolving in the receiver, gives the liquor a greenish colour; but from this it may be easily freed by a second distillation, when it rises with a very gentle heat,

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and becomes extremely white. Cryſtals of verdegris afford about one half their weight of radical vinegar; but verdegris itſelf much leſs, and of a more oily quality.

1527 Of its cryſtallization. If this acid be heated in a wide-mouthed pan, and fire applied to it, it will burn entirely away like ſpirit of wine. This obſervation we owe to the count de Lauragais, who has likewiſe obſerved, that it is capable of cryſtallization. This, however, takes place only with the laſt portions which came over, and the cryſtals appear in the form of plates or needles. The marquis de Courtrivon, who has repeated and confirmed the experiment of the count de Lauragais, ſuppoſes this phenomenon to be owing to a ſulphur-like mixture of acetous acid and phlogiſton. Leonhardi ſuppoſes an analogy between theſe cryſtals and the white ſalt of copper expelled at the end of the operation by the count de Laſſone. This ſalt was at firſt very white, and fixed on the neck of the retort pretty thick; but unleſs quickly collected, was ſoon deſtroyed by the ſucceeding vapours. When expoſed to the air, it attracts moiſture, and runs into a greeniſh liquid. It is uncommonly light, and in ſuch ſmall quantity, that ſcarce five or ſix grains can be collected from a pound of verdegris. Its taſte is acid, auſtere, very unpleaſant and permanent. It readily and totally diſſolves in water, and partially in ſpirit of wine, leaving a yellow powder totally ſoluble in volatile alkali, and which burns with a green flame. From this ſalt, volatile alkali acquires a blue colour, and litmus a red one; and thus it diſcovers itſelf to be compoſed of acetous acid and copper.

1528 Difference between radical vinegar and common acetous acid. Experience has ſhown that radical vinegar differs conſiderably in its properties from the common acid. It has a greater attraction for alkalies, forms with them more perfect combinations, and is leſs volatile. M. Berthollet obſerves, that when vinegar concentrated by froſt and radical vinegar, are reduced to equal denſities, by adding water to the heavier of the two, they differ very much both in ſmell and taſte. Laſſone found, that radical vinegar formed a cryſtallizable compound with volatile alkali; and Berthollet has obſerved the ſame with regard to fixed vegetable alkali. The cryſtals of the latter with radical vinegar were flat, tranſparent, and flexible, ſlowly deliqueſcent in the air. On comparing the ſalts formed by the two acids, he found, that the acetous ſalt rendered the ſyrup of violets green; but its colour remained unaltered with that made with radical vinegar. The latter alſo required a ſtronger fire to expel part of its acid; it was alſo whiter, and had a leſs acid taſte. On pouring radical vinegar on the acetous ſalt, the ſolution afforded, by evaporation and cryſtallization, a ſalt perfectly ſimilar to that procured directly from radical vinegar and fixed alkali. On diſtilling the mixture, the radical vinegar appeared to have expelled the common acetous acid, as the liquor which came over effervesced with vegetable alkali, and formed with it a terra foliata tartari.

"It ſeems probable (ſays Mr Keir), that the radical vinegar contains a larger portion of the aerial principle than the common acetous acid; by which it undergoes a change ſimilar to that of marine acid, when brought into that ſtate in which it is ſaid to be dephlogiſticated. This air it may acquire from the metallic calx, which being deprived of its air is reduced to its metallic ſtate. Thoſe who believe in the phlogiſton of metals, may ſay that the acid is dephlogiſticated by imparting its phlogiſton to the metal, which is thereby metallized. It appears, however, to be very diſtinct from common acetous acid, and deſerves to have its properties and compounds farther inveſtigated."

1529 How to obtain it pure from terra foliata tartari. Concentrated acetous acid, of a great degree of ſtrength may alſo be obtained by diſtilling terra foliata tartari with vitriolic acid; but Leonhardi obſerves, that the acid thus obtained is always more or leſs contaminated with the volatile acid of ſulphur. He obſerves alſo, that the method propoſed of ſeparating the ſulphureous acid by a ſecond diſtillation from ſalt of tartar is not effectual, becauſe the ſulphureous acid has leſs attraction for alkalies than the acetous. Weſtendorf recommends the neutral ſalt formed by acetous acid and mineral alkali, inſtead of the terra foliata tartari. Thus, in the firſt place, we readily obtain cryſtals free from the inflammable matter of the vinegar; and, in conſequence of this, though we diſtil it afterwards with concentrated oil of vitriol, no ſulphureous taint can be produced. Even ſuppoſing this to be the caſe (he ſays), it may be removed by a ſecond diſtillation from ſome mineral alkali. Mr Keir, however, obſerves, that "probably all the acids diſtilled from acetous ſalts by means of the vitriolic, partake of the property of that procured by diſtilling cryſtals of verdegris; and none of them can compare with that from which Mr Louitz obtained acetous ether without addition, as a pure concentrated and unaltered vinegar."

XIV. *Acid of Benzoin*.

1530 M. Lichtenſtein's account of its properties. The properties of this acid have been inveſtigated by M. Lichtenſtein, and are as follow. 1. Expoſed to the heat of a candle in a ſilver ſpoon, it melts as clear as water, without burning, though it is deſtroyed by contact of flame. 2. When thrown upon coals, it evaporates, without reſiduum, in a thick white ſmoke. 3. It is not volatile without a conſiderable degree of heat. 4. By very ſlow cooling its aqueous ſolution yields large cryſtals, long, thin, and of a feathery ſhape. 5. It is ſoluble in the concentrated acids of nitre and vitriol, but ſeparates from them, without decompoſition, on the addition of water. 6. By the other acids it cannot be diſſolved without heat, and ſeparates from them alſo without any change, merely by cooling. 7. It is copiouſly diſſolved by ſpirit of wine, and precipitated from it on the addition of water. 8. With alkalies it forms neutral ſalts, very ſoluble in water, and of a ſharp ſaline taſte. With vegetable alkali it forms cryſtals of a pointed feathery form: with mineral alkali it yields larger cryſtals, which fall into powder on being expoſed to the air; and with volatile alkali it is difficultly cryſtallizable into ſmall, feathery, and deliqueſcent cryſtals. It is ſeparable from alkalies by the mineral acids. 9. With calcareous earth it forms white, ſhining, and pointed cryſtals, not eaſily ſoluble, and which have a ſweetiſh taſte without any pungency. 10. With magneſia ſmall

Acetous acid.

ſmall feathery cryſtals are formed, of a ſharp ſaline taſte, and eaſily ſoluble in water. 11. An aſtringent ſalt is formed with earth of alum.

All theſe earthy ſalts are eaſily decompoſed by the mineral acids as well as by alkalies. The acid of benzoin itſelf reddens litmus, but has little effect upon ſyrup of violets.

1531. Effects of nitrous acid upon it.

Meſſrs. Hermbſtadt and Lichtenſtein have both tried the effects of nitrous acid upon that of benzoin. In this operation, however, a great obſtacle aroſe from the volatility of the acid of benzoin, which prevented it from bearing any conſiderable heat without paſſing over into the receiver. By repeated diſtillations, however, the acid of benzoin, diminiſhed in its volatility, aſſumed a darker colour, and acquired a bitteriſh taſte. A coal was alſo left at the bottom; and, at the end of the third operation, when the nitrous acid had been all drawn off, M. Hermbſtadt obſerved that ſome brown drops came over which had the appearance of a dark-coloured tranſparent oil, ſoluble in diſtilled water, emitting acrid fumes, and having a very cauſtic taſte. On diſtilling this acid liquor a ſecond time, a yellow ſaline maſs was obtained, which, when diſſolved in diſtilled water, formed a fluid acid, which precipitated a ſolution of ſugar of lead and lime-water. On examining the charred reſiduum left in the retort, he obſerved, that, after calcination, ſome of the earth had been vitrified, while another was of a ſoft conſiſtence, and had acquired a cauſtic taſte. From a mixture of the abovementioned dark-brown acid and ſpirit of wine, he obtained an ether, which differed from the nitrous in being much leſs volatile, and ſmelling like bitter almonds.

From this reſiduum Mr Lichtenſtein obtained a reſinous ſubſtance, to which he aſcribes the volatility of the acid of benzoin, as well as the ſmell of bitter almonds already mentioned.

Scheele failed in his attempt to obtain ether from flowers of benzoin and ſpirit of wine; but, by adding a little ſpirit of ſalt, he obtained a kind of ether which fell to the bottom. On diſſolving this in alkalized ſpirit of wine, and drawing off the latter by diſtillation, he obtained from it a quantity of flowers of benzoin.

1532. Acid of benzoin procurable from Peruvian balſam and urine.

From Peruvian balſam alſo Lehman obtained a quantity of the acid of benzoin. It may alſo be procured from urine, either by precipitation, from the ſaponaceous extract (A), or by repeatedly diſtilling from it ſpirit of nitre, as in the preparation of acid of ſugar. In the urine it is found combined with volatile alkali, by which it becomes ſoluble in ſpirit of wine.

XV. *Sebaceous Acid.*

This is ſaid to have been firſt diſcovered by Mr Gruitzmacker, who publiſhed an account of it in 1748. It was afterwards more accurately treated of by Mr Rhades in 1753. Its properties were inveſtigated by Meſſrs Segner and Knappe in 1754; and afterwards more fully by Dr Crell, of whoſe diſcoveries an account is given in the Philoſophical Tranſactions for 1780 and 1782.

Sebaceous acid.

1533. Sebaceous acid procurable from various ſubſtances.

It is found not only in the fat of all animals, but in ſpermaceti, the butter of cocoa, and probably in other vegetable oils. In ſeveral reſpects it ſeems analogous to the marine acid; but in others it is remarkably different, particularly in precipitating a ſolution of corroſive ſublimate. It is probable, however, that is principles are the ſame with thoſe contained in all other vegetable and animal acids; and this opinion is ſupported by what happens on treating tallow in the uſual manner for obtaining acid of ſugar; for thus, not the ſebaceous, but the ſaccharine acid is found to be produced.

1534. Has a remarkable power of attraction.

It has a very great ſtrength of attraction, and by means of heat decompounds even the vitriolic ſalts themſelves; but in the moiſt way is expelled by the three mineral acids, though it expels all the vegetable ones as well as thoſe of fluor and arſenic.

1535. Remarkable effect on tin.

Its moſt remarkable property is its effect on tin. The filings of this metal, eſpecially with the aſſiſtance of heat, are corroded by it into a yellow powder, and at the ſame time give out a very fetid ſmell. The ſolution, though filtered, ſtill continues turbid, and depoſits more yellow powder, acquiring at the ſame time a fine roſe-red colour. By adding water to this yellow powder, a white deliqueſcent ſalt may be obtained, and a ſimilar one obtained by diſſolving a yellow powder precipitated by this acid from ſolution of tin in aqua-regia.

1536. Its effects on other ſubſtances.

It corrodes lead rather than diſſolves it; but diſſolves a conſiderable quantity of minium, and changes the reſt to a white powder. This ſolution is ſweetiſh, and is not precipitated by common ſalt. The metal is precipitated by ſebaceous acid from the nitrous, in white needle-like cryſtals, eaſily ſoluble in water. A like precipitation takes place in ſolution of ſugar of lead; but the precipitate is ſtill ſoluble in ſtrong vinegar, provided it be not adulterated with oil of vitriol. In its elective attractions it agrees with the acids of apples and of fluor, preferring magneſia to fixed alkali.

XVI. *Acid of Galls.*

Though it has for a long time been known that the infuſion of galls has the property of reddening vegetable juices, diſſolving iron, and decompoſing liver of ſulphur, theſe effects were generally aſcribed to its aſtringency. Of late, however, it has been found, that beſides this aſtringent principle a true acid exiſts in galls; and to this, rather than to the aſtringent principle, are we to aſcribe the properties of galls in ſtriking a black with ſolution of vitriol, &c.

1537. Method of ſeparating the acid.

To ſeparate the acid from the other matters contained in the galls, we muſt add fixed alkali to a decoction of them; by which means the aſtringent matter will be thrown down, and the acid remain in the liquor joined to the alkali, the precipitate, waſhed with clean water, dried, and rediſſolved, blackened a ſolution of vitriol but faintly, and no more than what may be ſuppoſed to proceed from ſome remaining acid, which could not be abſtracted. This is proved by diſtilling

(A) By this is meant urine evaporated to a thick conſiſtence, and deprived of moſt of its ſalts by ſolution in ſpirit of wine.

Acid of galls.

ſtilling the aſtringent matter in queſtion, when an acid liquor comes over, which has the property of blackening ſolution of vitriol. Scheele has obſerved, that

1538 An acid obtained from galls by diſtillation.

when galls in ſubſtance are expoſed to diſtillation, an acid liquor riſes of an agreeable ſmell, without oil, and afterwards a kind of volatile ſalt, which is the true acid of the galls. Hence he infers, that this ſalt is contained ready formed in the galls themſelves; but ſo much involved in ſome gummy or other matter, that it cannot be eaſily obtained ſeparately.

The acid of galls is capable of being ſeparated by cryſtallization. In an infuſion made with cold water, Scheele obſerved a ſediment which appeared to have a cryſtalline form, and which was acid to the taſte, and had the property of blackening ſolution of vitriol. By expoſing the infuſion for a long time to the air, and removing from time to time the mouldy ſkin which grew upon it, a large quantity of ſediment was formed. On rediſſolving this in warm water, filtering and evaporating it very ſlowly, an acid ſalt was obtained

1539 Properties of this acid.

in ſmall cryſtals like ſand, which had the following properties: 1. It taſted acid, effervesced with chalk, and reddened litmus. 2. Three parts of boiling water diſſolved two of the ſalt; but 24 parts of cold water were required to diſſolve one. 3. It is likewiſe ſoluble in ſpirit of wine; four parts of which are required to diſſolve one of the ſalt when cold, but only an equal quantity when aſſiſted by a boiling heat. 4. The ſalt is deſtructible by an open fire, melts and burns with a pleaſant ſmell, leaving behind a hard inſoluble coal, which does not eaſily burn to aſhes. 5. By diſtillation an acid water is firſt obtained without any oil: then a ſublimate, which remains fluid while the neck of the retort is hot, and then cryſtallizes. This ſublimate has the taſte and ſmell of flowers of benzoin; is ſoluble in water and in ſpirit of wine; reddens litmus; and precipitates metallic ſolutions of the following colours, viz. gold of a dark brown; ſilver of a grey colour; copper of a brown; iron of a black; lead of a white colour; mercury of an orange; biſmuth, lemon-coloured. The acid of molybdæna became yellow coloured, but no precipitate enſued. Solutions of various kinds of earths were not altered; but lime-water afforded a copious grey-coloured precipitate. 6. By treating this acid with that of nitre, in the manner directed for producing acid of ſugar, it was changed into the latter.

XVII. *Identity of the Vegetable Acids.*

1540 Mr Keir's objections to the opinions on this ſubject.

On the proofs of the identity of the vegetable acids with one another, Mr Keir makes the following remarks: "The experiments and obſervations which have been made, prove evidently a ſtrong analogy between the acetous acid, ſpirit of wine, tartar, and acid of ſugar; and they ſeem to ſhow the exiſtence of a common principle or baſis in all of them, modified either by the addition of another principle not common to all of them, or by different proportions of the ſame principle. None of the opinions on this ſubject, however, are quite ſatisfactory. The production of the acetous acid by treating ſpirit of wine with other acids, does not prove that the acetous acid was contained in the ſpirit of wine, but only in concurrence with them, that they contain ſome common principle. There is no fact adduced to ſupport Morveau's opinion, that fixed air is abſorbed during the acetous fermentation; or that the preſence of this fixed air is neceſſary. The decompoſition of all vegetable acids by heat, and the production therefrom of fixed and inflammable gaſes, ſhow that theſe acids contain ſome of the ſame principles as theſe elaſtic fluids, but do not prove that the gaſes exiſted in the fluids. We have good reaſon to believe that acetous acid does not contain any fixed air already formed; for it yields none when vitriolic acid is added to it, or to foliated earth; nevertheleſs, my opinion that vegetable and animal acids are, by heat, in a great meaſure convertible into fixed air, ſeems to be ſufficiently proved by experiments. Thus Hales has ſhown the great quantities of this gas which tartar yields on diſtillation. Berthollet has obtained the fixed and inflammable gaſes from foliated earth; and Dr Higgins has verified this experiment, and deduced the quantities. From 7680 grains of foliated earth, the Doctor obtained.

Indentity of the vegetable acids.

1542 Quantities of the different ſubſtance obtained from foliated earth.

Cauſtic alkali -	3862.994 grains.
Fixed air -	1473.564
Inflammable air -	1047.6018
Oily matter retained in the reſiduum - -	78
Oil - - -	182
Water condenſed -	340
Deficiency attributed chiefly to water - -	726.9402"

As fixed and inflammable gaſes may be obtained from every vegetable ſubſtance by fire, nothing can be inferred from theſe experiments to explain particularly the nature of the acetous acid, excepting that it contains ſome of the inflammable matter common to the vegetable kingdom, and eſpecially of the matter common to vegetable acids; all which alſo, when analyſed, furniſh large quantities of theſe two gaſes.

"Although we are far (adds our author) from the knowledge requiſite to give a complete theory of the acetous fermentation, yet it may be uſeful to explain the ideas that appear moſt probable. In all the inſtances that we know of the formation of acids, whether effected by combuſtion, as the acids of ſulphur and phoſphorus, or by repeated abſtractions of nitrous acid, as in the proceſs for making acid of ſugar, a very ſenſible quantity of pure air is abſorbed. In the caſe of combuſtion we know, from the weight acquired, that there is a great abſorption of air; and in the latter caſe, of acids being produced by application of nitrous acid, as this acid conſiſts of nitrous and pure air, and as in theſe operations a quantity of the nitrous gas is expelled, there ſeems but little doubt that there alſo the pure air of the nitrous acid is united with the ſubſtance employed in the formation of the new acid. Hence, from all that we know, the abſorption of air takes place in all acidifying proceſſes. But it alſo actually takes place in the acetous fermentation, as has been obſerved, particularly by the Abbe Rozier; and it is generally known, that air is neceſſary to the formation of vinegar. The next queſtion is, What is the baſis? And from the experiments already related, of forming the acetous acid by means of ſpirit of wine, it ſeems probable, either that this ſpirit is the baſis of the acetous acid, or that it contains this baſis: and from the convertibility of the acids of tartar and of ſugar

1543 Air abſorbed in the formation of all acids.

Identity of the vegetable acids.

sugar into the acetous acid by the processes above described, it seems probable that these also contain the same common basis; which, being united with a determined quantity of pure air, forms acid of tartar; with a larger quantity, acid of sugar; and with a still larger, the acetous acid.

1544 Inflammable spirit produced from radical vinegar.

"An inflammable spirit is said to appear at the end of the distillation of radical vinegar from verdigris. Now, if the ardent spirit were contained in the verdigris, as it is more volatile than the acid, it ought to come over first; but as it appears only towards the end of the distillation, it seems to be formed during the operation; and I imagine, that the metal, when almost deprived of its acid, attracts some of the air of the remaining acid; and the part or basis of the acid thus deprived of its air becomes then an inflammable spirit, and in some cases an oil appears. But as the quantity of acid thus decomposed is very small, and little air of consequence remains united with the metallic part of the verdigris, the copper appears rather in a metallic than calciform state after the operation. But zinc, during its solution in concentrated vinegar, decomposes the acid as it does the vitriolic and other

1545 Sulphureous inflammable vapours produced from it.

strong acids, and accordingly inflammable vapours are produced; and what is remarkable, these vapours have a sulphureous smell. Iron always, during its solution in concentrated vinegar, produces an expulsion of inflammable vapours; which, however, do not explode like inflammable gas.

1546 Of the constituent parts of the acetous acid.

"We must not imagine that we are yet able to explain completely what passes in the acetous fermentation, or that the acetous acid is a compound of mere spirit and pure air. Besides this combination of spirit and air, it is observed, that a precipitation always takes place before the fermentation is completed, of some mucilaginous matter, which disposes the vinegar to putrefy, and from which it therefore ought to be carefully separated. Stahl affirms, that without a deposition of such sediment, vinegar cannot be made from sugar, wine, or other juice. Besides the matter that is deposited, probably as much remains in the liquor as can be dissolved therein; for, by distillation, much of a similar extractive matter is left in the retort. What the nature of this matter is, and how it is formed, has not yet been examined. Though distillation frees the acid from much of this extractive substance, yet we have no reason to believe that we have ever obtained it entirely free from inflammable matter; as it retains it even when combined with alkalies and with metals. When sugar of lead and other acetous salts are distilled with a strong heat, the substances remaining in the retort have been observed to possess the properties of a pyrophorus; and this will happen whatever pains have been taken to purify the vinegar employed. See the article PYROPHORUS. This fact shows the existence of an inflammable matter in this acid; and which may perhaps be essential in its com-

1547 It is formed in various chemical processes.

position, and necessary to its properties. Although fermentation is the usual mode of obtaining acetous acid, yet it appears from the instances observed by latter chemists, that it is not essential to its formation, but that it is also formed in various chemical processes; and the acid obtained by distillation from woods, wax, &c. are very analogous to vinegar. It appears also on treating the acid of sugar with nitrous acid, as has been observed both by Westrumb and Scheele. The latter further acquaints us, that he obtained it in analysing a tallow like oil, which remained undissolved upon digesting starch in nitrous acid. As acid of sugar also may be obtained from a variety of animal substances, and as this acid is convertible into the acetous we have one reason more added to many others, to prove that the matters of vegetable and animal substances are not capable of any chemical distinction."

Addition to Sect. I. § 20.

XVIII. ADDITION *to* Sect. I. § 20. *concerning the volatility of a Mixture of* MARINE *and* NITROUS ACIDS.

1548 How to deprive aqua-regia of its volatility.

THIS is much less sensible when the acids are weak than when they are concentrated. On mixing the two when moderately smoking, and which had remained for a long time separate without occasioning any disturbance, a vastly smoking aqua-regia has been produced, which would either drive out the stopple, or burst the bottle in warm weather. On distilling a pretty strong nitrous acid from sal ammoniac, M. Beaumé observed, that the vapours which came over were so exceedingly elastic, that notwithstanding every precaution which could be taken in such a case, the distillation could not be continued. By letting this escape, however, Mr Cornette observed, that the distillation of these two substances may be carried on to the end without any inconvenience, and the aqua-regia will then be no longer troublesome.

XIX. *TEST for* ACIDS *and* ALKALIES.

THE general method recommended for discovering a small quantity of acid or alkali in any liquid, is by trying it with any vegetable blue, such as syrup of violets; when, if the acid prevails in the liquor, the syrup will acquire a red colour, more or less deep according to the quantity of acid; or if the alkali prevail, it will change the syrup green in like proportion.

1549 Inaccuracy of the common tests.

Since the late improvements in chemistry, however, the syrup has been found deficient in accuracy, and the infusion of turnesole, or of an artificial preparation called litmus, have been substituted instead of it. The infusion of litmus is blue, and, like syrup of violets, becomes red with acids. It is so sensible that it will discover one grain of oil of vitriol though mixed with 100,000 of water. Unfortunately, however, this infusion does not change its colour on mixture with alkalies; it is therefore necessary to mix it with just as much vinegar as will turn the infusion red, which will then be restored to its blue colour by being mixed with any alkaline liquor. The blue infusion of litmus is also a test of the presence of fixed air in water, with which it turns red, as it does with other acids.

The great sensibility of this test would leave very little reason to search for any other, were it always an exact test of the point of saturation of acids and alkalies; but, from the following fact, this appears to Mr Watt to be dubious. A mixture of phlogisticated nitrous acid with an alkali will appear to be acid by the test of litmus, when other tests, such as the infusion of the petals of the scarlet rose, of the blue iris, of violets, and of other flowers, will show the same liquor to be alkaline, by turning green so evidently as to leave no room to doubt.

When Mr Watt made this discovery, the scarlet ro-

Teſt for acids and alkalies.

lies, and ſeveral other flowers, whoſe petals change their colour by acids and alkalies, were in flower. Having ſtained paper with their juices, he found that it was not affected by the phlogiſticated nitrous acid, excepting in ſo far as it acted the part of a neutralizing acid; but he found alſo, that, paper ſtained in this manner was much leſs eaſily effected than litmus was; and that, in a ſhort time, it loſt much of the ſenſibility which it poſſeſſed at firſt; and having occaſion in winter to repeat ſome experiments in which the phlogiſticated nitrous acid was concerned, he found his ſtained paper almoſt uſeleſs. Searching, therefore, for ſome other vegetables which might ſerve for a teſt at all ſeaſons of the year, he found the red cabbage to anſwer his purpoſe better than any other; having both more ſenſibility with regard to acids than litmus, being naturally blue, and turning green with alkalies, and red with acids; to all which is joined the advantage of its being no farther affected by the phlogiſticated acid of nitre than as it acts as a real acid.

1550 Red cabbage anſwers the purpoſe beſt.

1551 How to prepare it for uſe.

To prepare this teſt, Mr Watt recommends to take the freſheſt leaves of the cabbage; to cut out the large ſtems, and mince the thin parts of the leaves very ſmall; then to digeſt them in water at about the heat of 120 degrees for a few hours, when they will yield blue liquor; which, if uſed immediately as a teſt, will be found to poſſeſs great ſenſibility: but as in this ſtate it is very apt to turn putrid, ſome of the following methods muſt be uſed for preſerving it.

1. After having minced the leaves, ſpread them on paper, and dry them in a gentle heat; when perfectly dry, put them up in glaſs bottles well corked; and, when you want to uſe them, acidulate ſome water with vitriolic acid, and digeſt or infuſe the dry leaves in it, until they give out their colour; then ſtrain the liquor through a cloth, and add to it a quantity of fine whiting or chalk, ſtirring it frequently, until it becomes of a true blue colour, neither inclining to green nor purple; when you perceive that it has acquired this colour, filter it immediately; otherwiſe it will become greeniſh by ſtanding longer on the whiting. This liquor will depoſit a ſmall quantity of gypſum, and, by the addition of a little ſpirit of wine, will keep good for ſome days; but will then become ſomewhat putrid and reddiſh. If too much ſpirit is added, it deſtroys the colour. If the liquor is wanted to keep longer, it may be neutralized by a fixed alkali inſtead of chalk.

2. As thus the liquor cannot be long preſerved without requiring to be neutralized afreſh juſt before it is uſed; and as the putrid fermentation which it undergoes, and perhaps the alkalies or ſpirit of wine mixed with it, ſeem to leſſen its ſenſibility; in order to preſerve its virtues while kept in a liquid ſtate, ſome freſh leaves of the cabbage, minced as above directed, may be infuſed in a mixture of vitriolic acid and water, of about the degree of acidity of vinegar; and it may be neutralized, as it is wanted, either by means of chalk, or of the fixed or volatile alkali. It muſt be obſerved, however, that if the liquor has an exceſs of alkali, it will ſoon loſe its colour, and become yellow; from which ſtate it cannot be reſtored; care ſhould therefore be taken to bring it very exactly to a blue, and not to let it verge towards a green.

3. In this manner, Mr Watt prepared a red infuſion of violets; which, on being neutralized, formed a very ſenſible teſt, though he did not know how long theſe properties would be preſerved; but he is of opinion that the coloured infuſions of other vegetables may be preſerved in the ſame manner by the antiſeptic power of the vitriolic acid, in ſuch a manner as to loſe little of their original ſenſibility. Paper freſh ſtained with theſe teſts, in their neutral ſtate, has ſufficient ſenſibility for many experiments; but the alum and glue which enter into the preparation of writing paper, ſeem, in ſome degree, to fix the colour; and paper which is not ſized becomes ſomewhat tranſparent when wetted; which renders ſmall changes of colour imperceptible. Where accuracy is required, therefore, the teſt ſhould be uſed in a liquid taſte.

1552 Various other teſts.

4. Our author has found that the infuſion of red cabbage, as well as of various flowers in water, acidulated by means of vitriolic acid, are apt to turn mouldy in the ſummer ſeaſon, and likewiſe that the moulding is prevented by an addition of ſpirit of wine. He has not been able to aſcertain the quantity of ſpirit neceſſary for this purpoſe, but adds it by little and little at a time until the proceſs of moulding is ſtopped.—Very ſenſible teſts are afforded by the petals of the ſcarlet roſe, and of the pink coloured lychnis treated in the abovementioned manner.

XX. *Volatile Alkali.*

1553 Volatile alkali prepared from nitrous acid and tin.

Mr Higgins claims the firſt diſcovery of the conſtituent parts of volatile alkali, or at leaſt of an experiment leading to it. "About the latter end of March 1785 (ſays he), I found that nitrous acid poured on tin filings, and immediately mixed with fixed vegetable alkali, generated volatile alkali in great abundance: ſo ſingular a fact did not fail of deeply impreſſing my mind, though at the time I could not account for it. About a fortnight after, I mentioned the circumſtance to Dr Brockleſby. He told me he was going to meet ſome philoſophical gentlemen at Sir Joſeph Banks's, and deſired I would generate ſome alkali to exhibit before them: accordingly I did; and had the pleaſure of accompanying him thither. The December following I mentioned the fact to Dr Caulet, and likewiſe the copious generation of volatile alkali from Pruſſian blue, vegetable alkali, and water; on which we agreed to make a ſet of experiments upon the ſubject. At preſent I ſhall only give an account of the following, which drew our particular attention. Into a glaſs cylinder, made for the purpoſe, we charged three parts of alkaline air, and to this added one part of dephlogiſticated air; we paſſed the electrical ſpark repeatedly in it, without apparently effecting the ſmalleſt change. When it had received about 100 ſtrong ſhocks, a ſmall quantity of moiſture appeared on the ſides of the glaſs, and the braſs conductors ſeemed to be corroded; when we had paſſed 60 more ſhocks in it, the quantity of moiſture ſeemed to increaſe, and acquire a greeniſh colour, though at this time the column of air ſuffered no diminution. On examining the air, it burned with a languid greeniſh flame, from which we inferred that the dephlogiſticated air was totally condenſed: it ſtill retained an alkaline ſmell; and the alkaline part was not readily abſorbed by water.

1555 Effects of the electric ſpark on it.

"From

Pruſſian blue.

"From Mr Cavendiſh's famous diſcovery of the conſtituent parts of water we could readily account for the loſs of the dephlogiſticated air in this experiment; but the quantity of water was more than we could expect from this: therefore water muſt have been precipitated from the decompoſed alkali; for volatile alkali, from its great attraction to water, muſt keep ſome in ſolution even in its aeriform ſtate. From the above circumſtances it might be expected,
1556 True compoſition of volatile alkali.
that a contraction of the column of air ſhould take place; but it muſt be conſidered, that the union took place gradually in proportion as the alkali was decompoſed; and that, in this caſe, the expanſion muſt equal the condenſation. During the ſpring of 1786 I had often an opportunity of mentioning different facts to Dr Auſtin relating to volatile alkali, who at that time was too much engaged to pay attention to the ſubject. In the end of Auguſt 1787, he gave me an account of a ſet of experiments which he had made, and which actually proved, that volatile alkali conſiſts of light inflammable and phlogiſticated airs; not knowing at that time what Meſſrs Houſman and Berthollet had done. Without depreciating the merit of theſe two gentlemen, Dr Auſtin has an equal claim to the diſcovery, laying aſide priority; as his experiments are as deciſive as theirs. Dr Prieſtley made the firſt ſtep towards our knowledge of volatile alkali."

XXI. *Prussian Blue.*

1557 Woulfe's teſt for mineral waters.

The acid of this ſubſtance, as far as it contains an acid, is ſuppoſed to be that of phoſphorus. Mr Woulfe propoſed a teſt of this kind for diſcovering iron in mineral waters, which, he obſerved, would not be affected by acids; but the lixivium deſcribed by him had the bad property of letting fall the Pruſſian blue it contains in a few weeks. The precipitate of copper, however, treated again with alkali, retained this property upwards of nine months. The volatile alkali, he obſerves, is diſſolved by the Pruſſian acid; and the cryſtals depoſited are rendered blue by the colouring matter, though the colour at firſt is loſt by the union
1558 Effect of it on various metallic ſolutions.
of the alkali with the ſubſtance already made. The metals were precipitated by this teſt of the following colours: Gold of a browniſh yellow, the precipitate afterwards becoming of a full yellow; platina of a deep blue, but when quite pure, of a yellow colour, turning ſlightly green. Silver in the nitrous acid was precipitated of a whitiſh colour; copper from all the different acids was precipitated of a deep brown colour, the liquid remaining greeniſh; green vitriol let fall a deep blue powder, leaving a colourleſs lixivium; ſugar of lead and muriated tin gave a white powder; nitrated mercury a white or yellowiſh precipitate; the Illfeld manganeſe a browniſh, but that from Devonſhire a blue, which firſt became aſh-coloured and then reddiſh. Nitrated biſmuth afforded a white precipitate, and the lixivium was ſlightly green: muriated antimony yielded a white precipitate, with a yellowiſh lixivium: vitriolated zinc a whitiſh: cobalt in aqua-regia a reddiſh white powder: the precipitate of arſenic and the different earths was commonly white.

XXIII. *New Chemical Nomenclatures.*

New chemical nomenclatures.

1. *Of that propoſed in* 1787 *by Meſſrs Morveau, Berthollet, Fourcroy, and Lavoiſier.*

When this nomenclature was firſt publiſhed, M. Lavoiſier informs us, that ſome blame was thrown upon the authors for changing the language, which had received the ſanction of their maſters, and been adopted by them. In anſwer to this, however, he urges, that Meſſrs Bergman and Macquer had expreſſed a wiſh for ſome reformation in the chemical language. Mr Bergman had even written to M. Morveau on the ſubject in the following terms. "Show no favour to any improper denomination: Thoſe who are already poſſeſſed of knowledge, cannot be deprived of it by new terms; thoſe who have their knowledge to acquire, will be enabled by your improvement on the language of the ſcience to acquire it ſooner."
1559 Bergman's letter to Morveau on this ſubject.

1560 Lavoiſier's explanation of the new nomenclature.

The following is M. Lavoiſiers explanation of the principles on which his new language is compoſed. "Acids conſiſt of two ſubſtances, belonging to that order which comprehends ſuch as appear to us to be ſimple ſubſtances. The one of theſe is the principle of acidity, and common to all acids; from it therefore ſhould the name of the claſs and genus be borrowed: The other, which is peculiar to each acid, and diſtinguiſhes them from one another, ſhould ſupply the ſpecific name. But in moſt of the acids, the two conſtituent principles, the acidifying and the acidifyed, may exiſt in different proportion, forming different degrees of equilibrium or ſaturation; this is obſerved of the *ſulphuric* and *ſulphureous* acid. Theſe two ſtates of the ſame acid we have expreſſed by varying the termination of the ſpecific name.

"Metallic ſubſtances, after being expoſed to the compound action of air and fire, loſe their metallic luſtre, gain an increaſe of weight, and aſſume an earthy appearance. In this ſtate they are, like acids, compound bodies, conſiſting of one principle common to them all, and another peculiar to each of them. We have therefore in like manner claſſed them under a generic name, derived from the principle which is common to them all. The name which we have adopted is *Oxide:* The peculiar names of the metals from which they are formed, ſerve to diſtinguiſh theſe compounds from one another.

"Combſtuible ſubſtances, which, in acids and metallic oxides, exiſt as ſpecific and peculiar principles, are capable of becoming, in their turn, the common principle of a great number of ſubſtances. Combinations of ſulphur, were long the only compounds of this ſort known: but of late the experiments of Meſſrs Vandermonde, Monge, and Berthollet, have ſhown that coal combines with iron and perhaps with various other metals; and that the reſult of its combination with iron are, according to the proportions, ſteel, plumbago, *&c.* It is alſo known from the experiments of M. Pelletier, that phoſphorus combines with many metallic ſubſtances. We have therefore arranged theſe different combinations together under generic names, formed from the name of the common ſubſtance, with a termination indicating this analogy; and have diſtinguiſhed them from each other by ſpecific names derived from the names of the peculiar ſubſtances.

"It

New chemical nomenclatures.

"It was found somewhat more difficult to form a nomenclature for the compounds of those three simple substances; because they are so very numerous, and still more, because it is impossible to express the nature of their constituent principles, without using more compound names. In bodies belonging to this class, such as neutral salts for instance, we had to consider, 1. the acidifying principle common to them all; 2. the acidifiable principle which peculiarizes the acid; 3. the saline, earthy, or metallic base, which determines the particular species of the salt. We have derived the name of each class of salts from that of the acidifiable principle, common to all the individuals of the class; and have then distinguished each species by the name of the *saline*, *earthy*, or *metallic* base peculiar to it.

"As salt, consisting of any three principles, may, without losing any of these principles, pass through different states by the variation of their proportions; our nomenclature would have been defective without expressions for these different states. We have expressed them chiefly by a change of termination, making all names of salts in the same state to end with the same termination."

2. *Nomenclature by M. Wiegleb.*

1562
Mr Wiegleb's nomenclature.

In Wiegleb's General System of Chemistry translated by Hopson, we have another nomenclature formed on different principles. In this he gives to fixed vegetable alkali the name of *Spodium*, from the Greek word σποδος *(ashes)*. The mineral alkali he calls *natrum*, the name by which it was anciently distinguished; and the volatile alkali *ammonium*, from sal ammoniac which contains it in great quantity. The compound salts may be distinguished into double, triple, and quadruple; though, in the scheme given in the work, the first division is omitted, as tending only to create confusion. The irregular salts, consisting of those which are triple and quadruple, are admitted. Such as are imperfect by reason of an excess of acid, he says, are best denominated by converting the adjective, expressive of the base, into a participle; a practice which, on many occasions, though countenanced by the authority of a late eminent writer, seems aukward and stiff. The excess of acid is denominated by the word *hyperoxys*, and a defect of it by *hypoxys*. Hence his denominations are formed in the following manner.

Salts with excess of acid. Cream of tartar, or *tartarus spodatus*, or *tartaroxys spodicus*. Acid vitriolated tartar, or vitriolum spodatum, *vitrioloxys spodicus*.

The salts which are imperfect from a defect of acid have their denominations by mentioning the base before the acid, and expressing the former substantively, the latter adjectively. Thus,

Salt of tartar, aerated vegetable alkali, spodium aerocraticum,	Oxyspodium, aerocraticum.
Aerated volatile alkali, ammoniacum aerocraticum,	Oxyammonium aerocraticum.
Chalk, or calx aerocratica,	Oxycalcitis aerocraticus.
Borax, or natrum boracicum.	Oxynatrum boracicum.

With respect to other terms, Mr Wiegleb expresses the acid with which any base is combined, by the termination *cratia*, from the Greek κρατος *(robur)*, added to it; excepting only those with the nitrous and muriatic acids: and these (for what reason does not appear) he calls *Aponitra* and *Epimuriæ*. His genera of salts are as follow.

1. Vitriols *(Sulphurocratia)*. 2. Nitres *(Aponitra)*. 3. Murias *(Epimuriæ)*. 4. Boraxes. 5. Fluoricrates. 6. Arsenicrates. 7. Barylithicrates, (those with acid of tungsten). 8. Molybdænocrates. 9. Photocrates, (with acid of phosphorus). 10. Electrocrates. 11. Oxycrates, (with the acetous acid); or *epoxycrates*, with the aerated acid). 12. Tartars; or, with the acid changed by fire, *pyro-tartars*. 13. Oxalidicrates. 14. Cecidocrates (with the acid of galls). 15. Citriocrates. 16. Melicrates (with the acid of apples). 17. Benzicrates. 18. Xylocrates. 19. Gummicrates. 20. Camphoricrates. 21. Aerocrates. 22. Galacticrates. 23. Gala-melicrates (with acid of sugar of milk). 24. Myrmecicrates. 25. Cyanocrates (with the colouring matter of Prussian blue). 26. Steatocrates. 27. Bombycicrates. 28. Zoolithocrates, (with acid of calculus).

On the subject of nomenclatures it is obvious to remark, that whatever may be the defects of the old one, we are ready to be involved in much greater difficulties by the introduction of a new one. Or supposing a new language to be adopted, where would be the security for its permanence? That which appears most specious at one period, may still be superseded by the refinements of another; and colourable pretensions would never be wanting to successive innovators. Hence a continual fluctuation, and an endless vocabulary. As the nomenclature first abovementioned, however, has attracted no small degree of attention, we shall here subjoin a scheme of it, as well for the satisfaction of our readers in general, as for the gratification of those in particular who may have imbibed the doctrines of its authors.

[Follows *The Whole-sheet Table.*]

IBITING THE CHEMICAL NOMENCLATURE,

E MORVEAU, LAVOISIER, BERTHOLLET, and DE FOURCROY, in May 1787.

EDUCED BY THE C.	III. THE SAME SUBSTANCES COMBINED WITH OXIGENE.		IV. THE SAME SUBSTANCES IN AN OXIGENATED GAZEOUS STATE.		V. THESE OXIGENATED SUBSTANCES NEUTRALIZED BY EHE ADDITION OF BASES.		VI. THE SAME PRIMARY SUBSTANCES COMBINED WITH OTHER SUBSTANCES BUT NOT AICIDIFIED.		
NAMES.	NAMES NEWLY INVENTED OR ADOPTED.	ANCIENT MAMÈS.	NAMES NEWLY INVENTED OR ADOPTED.	ANCIENT NAMES.	NAMES NEWLY INVENTED OR ADOPTED.	ANCIENT NAMES.	NAMES NEWLY INVENTED OR ADOPTED.	ANCIENT NAMES.	
— —	— —	— —	— —	— —	— —	— —	— —	— —	1
—	— —	— —	— —	— —	— —	— —	— —	— —	2
licated or *vital*	— —	— —	— —	— —	— —	— —	— —	— —	3
ble gas.	Water.	*Water.*	— —	— —	— —	— —	— —	— —	4
ated air, or *at-* *ric mephitis.*	The baſe of nitrous gas. Nitric acid. *With an exceſs of azote.* Nitrous acid.	*The baſe of nitrous gas.* *White nitrous acid.* *Fuming nitrous acid.*	Nitrous gas. Nitrous acid gas.	— —	Nitrate of potaſh. of ſoda, &c. Nitrite of potaſh.	*Common nitre.* *Cubic nitre.*	— —	— —	5
—	Carbonic acid.	*Fixed air*, or *cretaceous acid.*	Carbonic acid gas.	*Fixed air, mephitic air.*	Carbonate of lime. Carbonate of potaſh, &c Carbonate of iron, &c.	*Chalk.* *Effervescent alkalies.* *Ruſt of iron, &c.*	Carbure of iron.	*Plumbago.*	6
—	Sulphuric acid. *With leſs oxigene,* Sulphureous acid.	*Vitriolic acid.* *Sulphureous acid.*	 Sulphureous acid gas.	 *Sulphureous acid gas.*	Sulphate of potaſh. Sulphate of ſoda. Sulphate of lime. Sulphate of aluminous earth. Sulphate of barytes. Sulphate of iron, &c. Sulphite of potaſh, &c.	*Vitriolated tartar.* *Glauber ſalt.* *Selenite.* *Alum.* *Ponderous ſpar.* *Vitriol of iron, &c.* *Stahl's ſulphureous ſalt.*	Sulphure of iron. Sulphure of antimo. Sulphure of lead. Sulph. hydrogen. gas. Sulphure of potaſh. Sulphure of ſoda. Alkaline ſulphures with metals ſuſpended in them. Alkaline ſulphure with carbonaceous matters ſuſpended in it.	*Factitious iron pyrites.* *Antimony.* *Galena.* *Hepatic gas.* *Alkaline livers of ſulphur.* *Metallic livers of ſulphur.* *Liver of ſulphur with carbonaceous matters ſuſpended in it.*	7
—	Phoſphoric acid. *With a ſmaller proportion of oxigene,* Phoſphorous acid.	*Phoſphoric acid.* *Fuming* or *volatile phoſphoric acid.*	— —	— —	Phoſphate of ſoda. Calcareous phoſphate. Superſaturated phoſphate of ſoda. Phoſphite of potaſh, &c	*Phoſphoric ſalt with a baſe of natrum.* *Earth of bones.* *Haupt's ſal perlatum.*	Phoſphoriſed hydrogenous gas. Phoſphure of iron.	*Phoſphoric gas.* *Syderite.*	8
—	Muriatic acid *With an exceſs of oxigene,* Oxigenated muriatic acid.	*Marine acid.* *Dephlogiſticated marine acid.*	Muriatic acid gas. Oxigenated muriatic acid gas.	*Marine acid gas.* *Dephlogiſticated marine acid gas.*	Muriate of potaſh Muriate of ſoda. Calcareous muriate, &c Ammoniacal muriate. Oxigenated muriate of ſoda, &c.	*Febrifuge ſalt of ſylvius.* *Marine ſalt.* *Calcareous marine ſalt.* *Sal ammoniac.*	— —	— —	9
—	Boracic acid.	*Sedative ſalt.*	— —	— —	Borate ſuperſaturated with ſoda, *or* borax. Borate of ſoda, &c. *ſoda ſaturated with the acid.*	*Common borax.*	— —	— —	10
—	[illegible] acid.	*Acid of ſpar.*	Fluoric acid gas.	*Spathoſe gas.*	Fluate of lime, &c.	*Fluor ſpar.*	— —	— —	11
—	Succinic acid.	*Volatile ſalt of amber.*	— —	— —	Succinate of ſoda, &c.	— —	— —	— —	12
—	Acetous acid	*Diſtilled vinegar.*	— —	— —	of potaſh. of ſoda. [illegible]	*Terra foliata tartari.* *Mineral terra foliata.* [illegible]	— —	— —	13

	—	—	—	—	—	Oxide of nickel.	*Calx of nickel.*	—	—	—	—	—	—
	Regulus of cobalt.	—	—	—	—	Grey / Vitreous } oxide of cobalt.	*Calx of cobalt.*	Alkaline cobaltic oxides.	*Precipitates of cobalt again dissolved by alkalies.*	—	—	—	—
	— —	—	—	—	—	White / Yellow / Vitreous } oxide of bismuth.	*Magistery of bismuth*, or *white paint.* *Yellow calx of bismuth.* *Glass of bismuth.*	Sulphurated oxide of bismuth.	*Bismuth precipitated by liver of sulphur.*	—	—	—	
	Regulus of antimony.	—	—	—	—	Oxide of antimony { by the nitrous acid, by the muriatic acid, sublimated. vitreous.	*Diaphoretic antimony.* *Powder of Algarotti.* *Flowers* or *snow of antimony.* *Glass of regulus of antimony.*	Grey / Red / Orange / Vitreous } Sulphurated oxide of antimony. Alkaline oxide of antimony.	*Grey calx of antimony.* *Kermes mineral.* *Golden sulphur.* *Glass and liver of antimony.* *Rotrou's solvent.*	—	—	—	
	— —	—	—	—	—	Oxide of zinc. Sublimated oxide of zinc.	*Calx of zinc.* *Flowers of zinc, pompholix*, &c.	Sulphurated oxide of zinc.	*Precipitate of zinc by liver of sulphur* or *factitious blende.*	—	—	—	
	— —	—	—	—	—	Black / Red } oxide of iron.	*Martial æthiops,* *Astringent saffron of Mars.*	Sulphurated oxide of iron.	— —	—	—	—	
	— —	—	—	—	—	White oxide of tin.	*Calx*, or *putty of tin.*	Yellow sulphurated oxide of tin.	*Aurum mussivum.*	—	—	—	—
	— —	—	—	—	—	White / Yellow / Red / Vitreous } oxide of lead.	*Ceruse*, or *white lead.* *Massicot.* *Minium.* *Litharge.*	Sulphurated oxide of lead.	— —	—	—	—	—
	— —	—	—	—	—	Red / Green / Blue } oxide of copper.	*Brown calx of copper.* *Green calx of copper, or verdigris.* *Mountain blue.*	Ammoniacal oxide of copper.	— —	—	—	—	—
	— —	—	—	—	—	Blackish / Yellow / Red } mercurial oxide.	*Æthiops* per se. *Turbith mineral.* *Precipitate* per se.	Black / Red } sulphurated oxide of mercury.	*Æthiops mineral.* *Cinnabar.*	—	—	—	—
	— —	—	—	—	—	Oxide of silver.	*Calx of silver.*	Sulphurated oxide of silver.	— —	—	—	—	—
	— —	—	—	—	—	Oxide of platina.	*Calx of platina.*	— —	— —	—	—	—	—
	— —	—	—	—	—	Oxide of gold.	*Calx of gold.*	— —	— —	—	—	—	—
n.	*Vitrifiable earth, quartz, &c.*	—	—	—	—	— —	— —	— —	— —	—	—	—	—
rth.	*Clay*, or *earth of alum.*	—	—	—	—	— —	— —	— —	— —	—	—	—	—
	Terra ponderosa.	—	—	—	—	— —	— —	— —	— —	—	—	—	—
	Calcareous earth.	—	—	—	—	— —	— —	— —	— —	—	—	—	—
	— —	—	—	—	—	— —	— —	— —	— —	—	—	—	—
	Vegetable fixed alkali of tartar, &c.	—	—	—	—	— —	— —	— —	— —	—	—	—	—
	Mineral alkali, marine alkali, natrum.	—	—	—	—	— —	— —	— —	— —	—	—	—	—
	Fluor, or *caustic volatile alkali.*	Ammoniacal gas.		*Alkaline gas.*		— —	— —	— —	— —	—	—	—	—

ces in the lower part of this col. cannot be reduced into a gazeous state, and not only they, but several of those in the upper part; we have therefore changed at this place the title of the column, and substituted another,

DENOMINATIONS newly appropriated to several Substances, which are more compound in their Nature, yet enter into new Combinations withou

	2	3	4	5	6	7	8	9	10	11	12	13	14
ous ...er.	Glutinous matter, *or* gluen.	Sugar.	Starch.	Fixed oil.	Volatile oil.	The aroma, *or* aromatous principle.	Resin.	Extractive matter.	Extracto-resinous matter. { in which the extractive matter predominates.	Resinous extractive matter. { in which the resin predominates.	Feculum.	Alcohol, or spirit of wine.	Alcohol { of potash. of guaiacum. of scammoneum. of myrrh, &c.
age.	*Glutinous matter.*	*Saccharine matter.*	*Amylaceous matter.*	*Fat oil.*	*Essential oil.*	*Spiritus rector.*	*Resin.*	*Extractive matter.*			*Feculum.*	*Spirit of wine,*	*Alkaline tincture.* *Tincture of guaiacum* ——— *scammonium.* ——— *myrrh, &c.*

TABLE, ſhowing the Manner in which Natural Bodies, conſidered in a Chemical View, may be divided into Claſſes; with their ſeveral Subdiviſions; their Properties defined; and the Manner in which they are obtained, pointed out.

NATURAL BODIES, conſidered as the Objects of Chemiſtry, may be divided into the following Claſſes, viz.
1. Salts. 2. Earths. 3. Metals. 4. Inflammables. 5. Waters. 6. Airs.

I. SALTS.

These are ſoluble in water, ſapid, and not inflammable. They are either Acids or Alkalies.

I. *Acids* are diſtinguiſhed by turning ſyrup of violets red, or forming with alkalies neutral ſalts; and are ſuppoſed to conſiſt of dephlogiſticated air condenſed, as their acidifying principle. The different acids yet known are,

1. *Vitriolic, fixed.* The moſt ponderous of all fluids next to mercury, the moſt fixed in the fire, and the moſt powerful as a ſolvent of all the acids. Obtained chiefly from ſulphur by inflammation.
2. *Vitriolic, volatile.* Obtained alſo from ſulphur by inflammation; air being admitted during the proceſs. It acts leſs powerfully as a ſolvent than when in its fixed ſtate.
3. *Nitrous* or *Aquafortis:* a volatile fluid, generally met with of a reddiſh colour, and emitting noxious fumes, when in its concentrated ſtate; though this is found not to be eſſential to it, but owing to a mixture of phlogiſton. In its pure ſtate it is almoſt as colourleſs as water, and ſmokes very little. It is next in ſtrength to the vitriolic acid, and obtained chiefly from nitre. It conſiſts of dephlogiſticated and phlogiſticated air condenſed, and may be obtained by taking the electric ſpark for a long time in a mixture of theſe. By uniting with ſome metals it appears to be converted into volatile alkali.
4. *Muriatic,* or *ſpirit of ſea-ſalt.* A volatile fluid, generally of a fine yellow colour; though this alſo is owing to the admixture of foreign ſubſtances, generally of iron. Inferior in power to the former, and obtained from ſea-ſalt. Naturally this acid ſeems to be in an aerial ſtate, but eaſily contracts an union with water. On mixture with manganeſe, it is wholly converted into a yellow, and almoſt incondenſible vapour, called *dephlogiſticated ſpirit of ſalt*; but which, on mixture with inflammable air, recompoſes the marine acid.
5. *Fluor acid.* Obtained from a ſpecies of ſpar: has little acid power, but is remarkable for its property of corroding glaſs.
6. *Acid of borax,* or *ſedative ſalt.* Obtained from borax in the form of ſcaly cryſtals; found alſo naturally in ſome waters in Italy, and in certain minerals in other countries.
7. *Acetous acid.* Obtained by allowing any fermentable liquor to proceed in the fermentation till paſt the vinous ſtate. It is much leſs corroſive, and leſs powerful as a ſolvent, than the vitriolic, nitrous, or marine acids.
8. *Acid of tartar.* Procured from the hard ſubſtance called *tartar,* depoſited on the ſides of wine veſſels.
9. *Acid of ſugar.* Found naturally in the juice of ſorrel, and procured artificially by means of nitrous acid from ſugar and a great variety of other ſubſtances. Aſſumes a dry form.
10. *Acid of phoſphorus.* Obtained artificially from urine, and in large quantity from calcined bones; found naturally in ſome kinds of lead-ore; and in vaſt quantities in Spain united with calcareous earth. Aſſumes a ſolid form, and melts into glaſs.
11. *Acid of ants.* Procured from the animal from which it takes its name, by expreſſion or diſtillation, in a fluid form.
12. *Acid of amber.* Obtained in a ſolid form from amber.
13. *Acid of arſenic.* Obtained from that ſubſtance by means of nitrous acid. Is extremely fixed in the fire.
14. *Acid of molybdæna.* Procured from that ſubſtance by means of nitrous acid. Reſembles a fine white earth.
15. *Acid of lapis ponderoſus, tungſten,* or *wolfram.* Obtained as an acid, *per ſe,* from this ſubſtance by Mr Scheele; but its real acidity is denied by other chemiſts. Is in the form of a yellow powder.
16. *Acid of milk.* Obtained in a fluid form from that liquor.
17. *Acid of ſugar of milk.* Obtained in form of a white powder, by means of nitrous acid, from ſugar of milk.
18. *Lithiſiac acid* Obtained in a ſolid form from human calculus, by means of nitrous acid.
19. *Acid of benzoin.* Obtained in a ſolid form from that gum by ſublimation or lixiviation with quicklime.
20. *Acid of lemons.* Obtained from the juice of that fruit by cryſtallization.
21. *Sebaceous acid,* or *acid of fat.* Obtained in a fluid ſtate from ſuet by diſtillation.
22. *Acid of citrons.* Obtained in a fluid ſtate from the juice of that and other fruits.
23. *Acid of apples.* Obtained in a fluid ſtate from the juice of apples and other fruits.
24. *Acid of ſorrel.* Obtained in a ſolid form from the juice of that plant; the ſame with acid of ſugar.

II. *Alkalies.* Theſe turn ſyrup of violets green, and with acids form neutral ſalts. They are,

1. *Fixed vegetable,* or *Pot-aſh.* Always obtained from the aſhes of burnt vegetables. A deliqueſcent ſalt.
2. *Fixed foſſile.* A ſolid cryſtalline ſalt, ſometimes found native, as the natrum of Egypt; and ſometimes by burning ſea-weed as kelp.
3. *Volatile.* Obtained from ſal ammoniac, from the ſoot of burning bodies, and from the putrefactive fermentation. It is naturally in the ſtate of an inviſible and elaſtic vapour, conſtituting a ſpecies of aerial fluid, and conſiſts of phlogiſticated and inflammable air.

Acids, by their union with other bodies, form

Neutral Salts. Theſe are always compoſed of an acid and an alkali, and are of many different kinds, as may be ſeen in the following table.

Earthy Salts. Compoſed of an acid joined to an earthy baſis, as alum and gypſum. See the following table.

Metallic Salts. Formed of an acid and metal. The principal of theſe are vitriols; the others may be ſeen in the following table.

Essential Salts. Obtained from vegetables, and contain an acid joined with the juices of the plant in a particular manner not to be imitated by art. To theſe belong ſugar, manna, honey, and others of that ſort.

II. EARTHS.

These are solid bodies, not soluble in water, nor inflammable; and if fused in the fire, never resume their earthy form again, but take that of glass. They are divided into *absorbent*, *crystalline*, and *argillaceous*.

I. *Absorbent Earths* are capable of being united with acids, and are either calcareous, or not calcareous.

a, The calcareous absorbent earths are,

1. *Limestone*, or *marble*. This is of infinite variety as to colour and texture. Marble is the hardest and finest. Those kinds of limestone which feel unctuous to the touch, are generally impregnated with clay: those that feel gritty, or where the lime is hard and weighty, contain sand; this is the best for building; the other for manure.
2. *Chalk*. A white, friable, soft substance. This is much more free of heterogeneous matters than any limestone, and is easily calcined into quicklime. It is probably nothing else than limestone suddenly concreted without being crystallized.
3. *Sea shells*, are likewise a calcareous earth, and yield a very fine quicklime. These are used in medicine.
4. *Terra ponderosa*. A fine white earth sometimes found combined with fixed air, but more commonly with the vitriolic acid; and forming with it a very heavy compound, named *spathum ponderosum*. It is found in mines and veins of rocks.

b, The absorbent earths which cannot be reduced into quicklime are,

1. *Magnesia alba*. A white earth, usually found combined with the vitriolic acid, and forming bitter purging salt. It is likewise obtained from the mother-ley of nitre, the ashes of burnt vegetables, *&c*.
2. *Earth of alum*. A particular kind of absorbent earth, found in many places mixed with sulphureous pyrites, as in Yorkshire, &c. Clay of any kind may by a particular process be converted into this earth.
3. *Earth of animals*. This is obtained by the calcination of animal substances, and by precipitation in the process for making acid of milk. It can hardly be converted into glass; and is therefore used as a basis for white enamels, &c. It is said to consist of the phosphoric acid united to calcareous earth.

II *Crystalline or Vitrescent Earths*, are hard, and strike fire with steel; may be calcined in the fire; but are not soluble in acids. Of this kind are,

1. *Sand* and *Flint*; found plentifully every where. With alkaline substances they are easily changed into glass; and hence are termed *vitrescent*.
2. *Precious stones* of all kinds are likewise referable to this class; but they are of a much greater degree of hardness and transparency than the others.

III. *Argillaceous Earths* are distinguished by acquiring a very hard consistence when formed into a paste with water, and exposed to a considerable degree of heat; not soluble in acids. They are,

1. *Common clay*. It is of many different colours; but chiefly red, yellow, or white. The purest is that which burns white in the fire.
2. *Medical boles*. These are of different sorts; but are only a purer kind of clay, sometimes mixed with a little iron or other matters.
3. *Lapis nephriticus*, or *steatite*. These are indurated clays, found in various parts. They are at first soft and readily cut; but turn extremely hard in the air. Many other varieties of these earths might be mentioned; but as they do not differ in their chemical properties so much as in their external appearance, and being all mixed with one another, they more properly belong to the natural historian than the chemist.

III. METALLIC SUBSTANCES.

These are bodies of a hard and solid texture; fusible in the fire, and resuming their proper form afterwards; not miscible with water, nor inflammable. They are divided into *Metals and Semimetals*.

I. *Metals* are malleable; and the species are,

1. *Gold*. The most ponderous and fixed in the fire of all bodies except platina, and the most ductile of any. It has a yellow colour, and is more commonly found in its metallic state than any other metal. It has no proper ore; but is found in ores of silver, and almost all sands contain some of it.
2. *Silver* is next to gold in malleability and ductility; but less fixed in the fire than either it or platina. It is sometimes found in its native state; but most commonly in that of an ore with sulphur, sometimes with arsenic, and assuming different appearances.
3. *Platina*. A white metal of a greater specific gravity than gold, and altogether as fixed in the fire; the most difficult to be melted of all known substances; resisting the tests which have usually been applied for discovering the purity of gold, supposed from hence to be the *smiris* of the ancients. Found in South America.
4. *Copper*. Of a reddish colour, hard and sonorous; admits of being extended greatly under the hammer, either hot or cold. Is difficult of fusion. It is generally found in the state of an ore with sulphur. There are a great variety of ores of it, extremely beautiful, blue, red, green, and yellow.
5. *Iron*. A grey-coloured metal, extremely ductile when hot; the lightest of them all except tin. It is the only metal certainly known to admit of being welded; though platina is likewise said to possess some share of this property. It is likewise the only one capable of being tempered by cooling. It is found almost every where; and its ores are infinitely various.
6. *Tin*. A white soft metal, the lightest of the whole, and very ductile. The ores of it are generally arsenical, and assume a crystalline appearance; their colour being most usually of a dark brown, and sometimes very beautiful.

7. *Lead.* A metal of a dull bluifh colour, exceedingly foft and malleable, and very weighty. Seldom found in its metallic ftate, but ufually in an ore with fulphur or arfenic; but feldom with fulphur alone. The principal ores of it are the cubic, called *galena* and the glaffy, called *fpar*.
8. *Mercury or quickfilver*; formerly accounted a femimetal, on account of its fluidity, but now reckoned among the moft perfect metals. It is a white, opaque, metallic body; fluid, except in a very intenfe degree of cold; very heavy, and eafily volatilized by heat. Sometimes found in its fluid form, but ufually in a beautiful red ore with fulphur, called *cinnabar*.

II. *Semimetals* are brittle, and do not ftretch under the hammer. They are,

1. *Zinc.* A bluifh white fubftance of a fibrous texture, confiderably hard and fonorous, with a fmall degree of ductility; eafily fufed and volatilized. Its principal ore is lapis calaminaris.
2. *Bifmuth* or *tin-glafs.* A white ponderous, hard, brittle and fonorous body, of a plated texture; eafily fufed and vitrified. It is only reduced to an ore by arfenic. Its appearance much the fame with regulus of antimony.
3. *Antimony.* A blackifh fubftance, of a fibrous needle-like texture; hard, brittle, and of a confiderable weight; not difficult of fufion, and eafily convertible into glafs. Its only ore is with fulphur, which is the crude antimony.
4. *Arfenic.* A bright, fparkling, whitifh-coloured femimetal; of a plated texture; very brittle, and extremely volatile. It is generally found in the ores of others metals.
5. *Cobalt.* A brittle femimetal fufible in a moderate heat, and eafily convertible into a beautiful blue glafs, called *fmalt.* It is always obtained from an arfenical ore, likewife called *cobalt*.
6. *Nickel.* A reddifh white fubftance, of a clofe texture, and very bright; eafily melted, but very difficult to vitrify.

IV. INFLAMMABLE SUBSTANCES,

Are thofe which continue to burn of themfelves when once fet on fire. They are divided into *oils*, *fulphur* or *brimftone*, *alcohol* or *ardent fpirits* and *charcoal*.

I. *Oils* are thickifh, vifcous fluids, not mifcible with water. Divided into *animal*, *vegetable*, and *foffile*.

a, *b*, The animal and vegetable oils are,

1. *Expreffed.* Thefe are of a mild and bland tafte, inodorous, and not foluble in alcohol. They are obtained by expreffion, as oil of olives, rape-feed, almonds, &c. Animal fats are of the fame nature, as is alfo wax.
2. *Effential.* Thefe are always obtained by diftillation, poffefs the tafte and flavour of the fubject from whence they are drawn, and are foluble in alcohol. Of this kind are oil of cloves, fpike, &c. The oil of ants is an example in the animal kingdom.
3. *Empyreumatic.* Thefe are obtained by a confiderable degree of heat, and poffefs an acrid tafte and burnt-like flavour, as oil of hartfhorn. They are foluble in fpirit of wine.

c. *Foffile oils.* Thefe are found in the earth in their native ftate; and are called, when pure, *naphtha*; which is of an acrid tafte, and extremely volatile, not mifcible with alcohol. A great many inflammable foffils contain this, as bitumens, pit-coal, &c.

II. *Sulphur or Brimstone.* This is a dry friable fubftance, not mifcible with water. It is found in many mineral fubftances, metallic ores, &c. but is for the moft part met with in pyrites. Great quantities of it are found in the neighbourhood of volcanoes.

III. *Alcohol or Ardent Spirits.* This is a fluid of an acrid and volatile nature, mifcible with water; obtained from fermented vegetable juices by diftillation; as from the juice of the grape, malt-liquors, rice, &c.

IV. *Charcoal.* The refiduum of moft inflammable matters after undergoing diftillation with a ftrong fire. A black fubftance, acted upon with difficulty by acids; foluble in hepar-fulphuris, and entirely diffipable into inflammable air by a very violent heat. Of great ufe as fuel, and effentially neceffary in metallurgy and other arts.

V. WATER.

A colourlefs infipid fluid well known. It is either *fimple* or *mineral*.

I. *Simple*, or *pure-rain-water*, as it called, though the moft homogeneous fluid of this kind with which we are acquainted, is not perfectly pure, but always contains a portion of mucilaginous matter, which can never be perfectly feparated. It is fuppofed to confift of dephlogifticated and inflammable air condenfed.

II. *Mineral waters* are thefe fpring-waters impregnated with faline fubftances; the diverfity of which is exceeding great; but they all agree in having an acid joined with them. The moft common forts are impregnated with iron and fulphur.

VI. AIR.

An invifible and permanently elaftic fluid, is of the following kinds: *Dephlogifticated*, *phlogifticated*, *fixed* or *fixable*, *inflammable*, *nitrous*, *vitriolic acid air*, *marine acid air*, *dephlogifticated marine acid*, *alkaline air*, *hepatic air*, *atmofpherical air*.

1. *Dephlogifticated.* An elaftic fluid naturally extricated in the procefs of vegetation; artificially procured from nitre, minium, manganefe, water, &c. eminently capable of fupporting flame and animal life. One of the component parts of our atmofphere.

2. *Phlogisticated*. Produced in great quantities during the putrefactive fermentation; obtained also in the calcination of metals and other phlogistic processes. Destroys animal life, and extinguishes flame, but is very friendly to vegetation. Is another of the component parts of our atmosphere.

3. *Fixed*, or *fixable*. Has its name from the property of adhering to certain bodies, and fixing itself in them. Consists of dephlogisticated air united to charcoal. Is obtained by fermentation, and in all phlogistic processes. Manifests the properties of an acid: extinguishes flame, and destroys animal life.

4. *Inflammable*. Consists wholly of charcoal and a little water rarefied by heat; is remarkable for being the lightest of all gravitating substances. Is produced naturally in mines, and from putrid waters; artificially procured from certain metallic solutions, by passing the steam of water over red-hot iron; by distilling wood, pit-coal, &c. with a strong heat; or by exposing charcoal to the heat of a burning lens *in vacuo*. It extinguishes flame unless it be mixed with a certain proportion of atmospherical or dephlogisticated air; in which case it explodes violently, destroys animal life, but is friendly to vegetation.

5. *Nitrous*. Procured artificially in dissolving metallic or other substances in the nitrous acid. On mixture with dephlogisticated air both the fluids lose their elasticity, and a small quantity of nitrous acid is produced. It instantly kills animals, and extinguishes flame. By union with some metals is converted into volatile alkali. In some cases it may be made to support flame, and even animal life. Its property of condensing along with phlogisticated air renders it a test of the salubrity of the atmosphere.

6. *Vitriolic acid air*. The same with volatile or sulphureous vitriolic acid.

7. *Marine acid air*. The same with marine acid reduced into vapour, and deprived of most of its water.

8. *Dephlogisticated marine acid*. Supposed by some to be the marine acid deprived of its phlogiston; by others to be the same acid with an addition of pure air. It destroys many kinds of colours; whitens linen, and with inflammable air regenerates common marine acid.

9. *Alkaline air*. The same with pure volatile alkali; is formed by an union of phlogisticated and inflammable air.

10. *Hepatic air*. Produced from the decomposition of liver of sulphur by acids, or in the common atmosphere. It is inflammable, but does not burn with explosion.

11. *Atmospherical air*. Composed of dephlogisticated and phlogisticated air; and thus supports both animal life and vegetation.

TABLE, showing the several Combinations that the SIMPLE CHEMICAL ELEMENTARY BODIES admit of with one another; the Compound resulting from that Mixture; and the Manner in which the Union is effected: With some Account of the principal Uses to which these are applied in Arts or Manufactures.

N. B. This mark*, put above any word, denotes that there is some difficulty in the process, or that the union is not very complete.

VITRIOLIC ACID may be combined with the following substances, viz.

ACIDS.
- NITROUS ACID. A mixture which readily inflames oils. By solution, generating heat.
- MURIATIC, VEGETABLE, and all other ACIDS yet known. By solution, generating heat. But these mixtures are applied to no particular use in medicine or arts.

ALKALIES.
- VEGETABLE.
  - *Vitriolated tartar*. By solution and crystallization, or double elective attraction from a great variety of bodies.
  - *Nitrum vitriolatum*. A vitriolated tartar, obtained by distilling from nitre with the vitriolic acid.
  - *Sal polychrestum*. By deflagrating nitre with sulphur. There are many other kinds of vitriolated tartar, known formerly by different names, and supposed to be possessed of particular properties, but they are now neglected.
- FOSSILE. *Glauber's salt*. By solution and crystallization. Much used in medicine as a gentle purgative.
- VOLATILE. *Secret ammoniac*. By solution. Formerly supposed a most powerful menstruum for metals, &c. but without any just foundation.

EARTHS.
- CALCAREOUS EARTHS.
  - A corroded calx. By simple corrosion. This when perfectly edulcorated with water is found to be a true gypsum.
  - *Selenites*. By precipitation from a very dilute solution of chalk in the nitrous acid, by means of the vitriolic acid.
  - *Terra ponderosa*. With this it unites in preference to alkalies, forming a very heavy and insoluble substance called *spathum ponderosum*.
  - *Gypsum* or *Paris-plaster*. Often found in a native state. May be artificially formed by precipitating from a solution of chalk in a very concentrated nitrous acid. Used as a cement: for taking impressions from medals, &c.
  - *Talc asbestos, &c.* A native production which connot be perfectly imitated by art. Used for holding objects in microscopes, making incombustible cloth, &c.
- MAGNESIA. *Epsom*, or *magnesia Glauber's salt*. By solution and crystallization. Much used in medicine for the same purposes as real Glauber's salt.

EARTHS.

EARTHS.

- Earth of Alum. *Alum.* By ſolution, cryſtallization, &c. Uſed by dyers as a preparatory for taking on the colours, papermakers, goldſmiths, &c.
- Earth of Animals, Osteocella, &c. By ſolution. The mixtures of theſe are not applied to any particular uſe.
- Clay*. *Alum.* By digeſting pure clay for ſome time in this acid, and expoſing it for ſome time to the air, an alum is produced; and if the clay is precipitated from this aluminous concrete, it is found to be a pure earth of alum, ſoluble in all acids.
- Flint. A thickiſh coagulum. By digeſting the liquor ſilices in the vitriolic acid.

METALS.

- Gold*. Imperfectly. By a particular proceſs after being ſeparated from aqua-regia.
- Silver*. By ſolution, after it has been precipitated from the nitrous acid by alkalies. The fumes which ariſe in this ſolution are inflammable.
- Copper. *Blue vitriol.* This is ſometimes a native production, but in this way it is never pure. It is artificially prepared by ſolution in a very concentrated acid, and cryſtallizing it.
- Iron.
  - *Green vitriol* or *copperas.* Obtained at large by particular proceſs from pyrites; or by ſolution, &c. in a diluted acid. This is the baſis of all black dyes, ink, &c. as it ſtrikes a black colour with vegetable aſtringents.
  - *Salt of ſteel.* By calcining the cryſtals of green vitriol till they are converted into a white powder.
  - *Colcothar of vitriol.* By continuing the calcination till it aſſumes a brown colour.
- Lead.
  - *Saturnus vitriolicus.* A ſolution in a boiling heat, but is again precipitated when cold.
  - An indiſſoluble concrete. By precipitation from the nitrous acid.
- Tin. *Jupiter corroſivus.* By a boiling heat in a concentrated acid.
- Mercury.
  - *Ignis Gehenne*, or infernalis of Paracelſus. By a boiling heat, and repeated coctions with freſh acid when it is evaporated.
  - *Turpeth mineral*, or mercurius precipitatus flavus. By evaporating to dryneſs, and then waſhing with water.

SEMIMETALS.

- Antimony*. *A metallic ſalt.* By elective attraction from butter of antimony.
- Zinc. *White vitriol.* Often found in its native ſtate. Artificially made by ſolution and cryſtallization in a diluted acid. Uſed by painters for drying.
- Bismuth. A corroded calx. By ſolution in a concentrated acid.
- Arsenic - - - By ditto.
- Cobalt. A roſe-coloured mixture. By ſolution. If this is precipitated by a fixed alkali, and again diſſolved, the liquor appears of a beautiful red.

OILS.

- Expressed. A blackiſh gummy-like maſs. By ſolution, generating a conſiderable heat. Native gums are ſuppoſed to owe their origin to a mixture of this kind.
- Essential. A dark-coloured reſinous maſs. A great heat and violent effervеſcence being produced by this mixture. Native reſins ſuppoſed the ſame.
- Empyreumatic. Little known. By ſolution.
- Fossile. A ſubſtance reſembling amber. By ſolution.

SULPHUR*. Here there is no proper union of ſubſtances; but if ſulphur is boiled in this acid, it becomes leſs inflammable and more fixed than any ordinary ſulphur.

ALCOHOL.

- *Vitriolic ether.* By careful ſolution and diſtillation, the ether being ſeparated by the addition of water.
- *Spiritus vitrioli dulcis.* By ſolution and diſtillation.
- *Oleum dulce.* By continuing the heat after the ether has ariſen.
- *Oleum anodynum minerale.* By rediſtilling the reſiduum of the laſt with alcohol. A medicine much celebrated by Hoffman.
- *Sulphur.* By puſhing the heat after the oil comes over. It is to be obſerved that this is produced in every combination of this acid with inflammables or metals.

WATER. An acidulated water. Sometimes, though ſeldom, found iſſuing along with native ſprings. Applied to no particular uſe.

NITROUS ACID may be combined with the following Subſtances, viz.

ACIDS.

- Vitriolic, as above.
- Muriatic. *Aqua-regia.* By ſolution. This is the only proper menſtruum for gold; and it is a ſolution of tin in this menſtruum which is the baſis of the ſcarlet dye.
- Vegetable, and all others. By ditto. Theſe compounds have no particular names, nor are applied to any particular uſes in medicine or arts.

ALKALIES.

- Vegetable. *Common nitre.* A native production. Made artificially by ſolution and cryſtallization. This deflagrates with oily or metallic bodies, and is the foundation of gun-powder.
- Fossile. *Cubic nitre.* By ſolution.
- Volatile. *Nitrous ammoniac.* By ſolution. This differs from all the other ammonical ſalts, by being ſoluble in alcohol.

EARTHS.

- Calcareous.
  - *Deliqueſcent cryſtals.* By ditto and cryſtallization.
  - *Baldwin's phoſphorus.* By ditto and evaporating to dryneſs.
- Earth of Alum, and all other abſorbent earths. By ſolution. The compounds have no names nor any remarkable properties hitherto diſcovered.
- Crystalline Earths*. By ſolution after precipitation from the liquor ſilices.

METALS.

METALS.

- GOLD*. *Slightly impregnated.* By a boiling heat in cloſe veſſels, after the ordinary method of ſeparating ſilver from gold by the nitrous acid. It ſpontaneouſly ſubſides in the air.
- SILVER.
  - *A fluid ſolution.* By ſolution. This when diluted with water ſtains hair and bones black; as alſo marble, agate, jaſper, &c. of different colours.
  - *Sal metallorum.* By ſolution and cryſtallization.
  - *Catharticum lunare, lunar cauſtic,* or *lapis infernalis.* By inſpiſſating the ſolution to dryneſs.
- COPPER. A green-coloured ſolution. By ſolution.
- IRON. A greeniſh ſolution, if a diluted acid is employed; if otherwiſe, it is of a yellowiſh colour: evaporated to dryneſs, it deliquates in the air.
- LEAD.
  - A yellow ſolution. By diſſolving in a diluted acid. If much water is added, the metal is precipitated.
  - *Saturni fulminans.* By inſpiſſating the ſolution. This explodes when put upon the fire with greater force than nitre, and has been propoſed to be uſed as an ingredient in gun-powder to augment its force.
- TIN. A ſolution or corroded calx. By a careful ſolution without heat it remains ſuſpended; if otherwiſe, it falls down in form of a calx. This is commonly ſuppoſed to be the compoſition uſed in dyeing ſcarlet; but by miſtake: for it is a ſolution of tin in aqua-regia that communicates that fine colour to cochineal. The ſame ſolution is the baſis of the powder which tinges glaſs of a ruby colour. It is the precipitate of gold from aqua-regia by means of tin.
- MERCURY.
  - A limpid ſolution, intenſely corroſive. By ſolution.
  - *Red precipitate.* By evaporating the ſolution to dryneſs, and then calcining till it becomes red.
  - *Mercurius corroſivus fuſus.* By precipitating from the nitrous acid by fixed alkali.
  - *White precipitate* - By ditto with the volatile alkali.

SEMIMETALS.

- BISMUTH.
  - A greeniſh ſolution. By uſing a concentrated acid. This might be applied in ſome caſes in the art of dyeing; but is not yet come into general uſe.
  - *Magiſtery of biſmuth.* By precipitating from the ſolution by means of water. This has been employed as a coſmetic, but is inefficacious and unſafe. If mixed with pomatum, this ſtains hair of a dark colour without injuring it.
- ZINC. A corroded ſolution. By the ordinary means.
- ANTIMONY.
  - A colourleſs calx. By ſimple corroſion.
  - *Bezoardic mineral.* By diſtilling from butter of antimony, after having added the nitrous acid.
  - *Antimonium diaphoreticum.* By adding nitre to crude antimony, and deflagrating.
  - *Ceruſa antimonii.* By deflagrating regulus of antimony with nitre.
- COBALT.
  - A red liquor. By ſolution either in its calcined or metallic ſtate.
  - *Roſe-coloured cryſtals.* By adding muriatic acid, and allowing it to cryſtallize.
  - *Green ſympathetic ink.* By diſſolving theſe cryſtals in water. The ſolution is red when cold, and green when warm; when wrote with, it diſappears when dry; but when held to the fire it becomes green; and again diſappears when cold.
- NICKEL. A green-coloured liquor. By ſolution.

OILS.

- EXPRESSED. A thick bituminous-like ſubſtance. Upon the mixture a conſiderable degree of heat is generated, and ſometimes, though very ſeldom, actual flame is produced.
- ESSENTIAL. Ditto. A more violent heat is generated upon the mixture with theſe oils than any other, and with many of them an actual flame is produced.
- EMPYREUMATIC. This mixture has no name, nor is it applied to any remarkable uſe in arts.
- FOSSILE. Ditto.

ALCOHOL,

- *Nitrous ether.* By digeſting; the ether ariſing to the ſurface.
- *Spiritus nitri dulcis.* By digeſting a little, and then diſtilling.

WATER. *Acidulated water.* By ſolution.

The MURIATIC ACID *may be combined with the following Subſtances.* viz.

ACIDS.

- VITRIOLIC and NITROUS. As in the former part of this Table.
- VEGETABLE, and all others yet known. By ſolution: but as none of theſe mixtures are applied to any particular purpoſe, we take no notice of them.

ALKALIES.

- VEGETABLE. *Digeſtive ſalt.* By ſolution and cryſtallization.
- FOSSILE.
  - *Common ſalt.* Commonly obtained by evaporating ſea-water to dryneſs; or artificially made by mixing the acid and alkali, and cryſtallizing.
  - *Sal gem.* A native foſſile ſalt, found in mines in Poland, Spain, *&c.* of the ſame nature as common ſalt, but more pure.
- VOLATILE. *Common ammoniac.* Obtained at large by a particular proceſs from ſoot. Artificially made by mixing the acid and alkali, and cryſtallizing.

EARTHS.

- CALCAREOUS.
  - *Liquid ſhell.* By ſolution. A ſubſtance whoſe effects in medicine have been greatly extolled.
  - *Ol. calcis per deliquium.* By evaporating liquid ſhell to dryneſs. It naturally deliqueſces.
  - *Fixed ammoniac.* By ſolution and cryſtallization. This ſometimes appears luminous in the dark when ſtruck with a hammer.
- OSTEOCOLLA, MAGNESIA, and other abſorbents. By ſolution: but the properties or uſes of theſe are not known.

METALS.

METALS.

- GOLD*, *A yellow liquor.* By boiling a calx of gold (in whatever way obtained) in this acid. It does not act upon it in its metallic ſtate.
- SILVER*.
  - *A fluid ſolution.* By diſſolving the ore of ſilver in this acid. It does not act upon pure metallic ſilver.
  - *Luna cornea.* By elective attraction from the nitrous acid.
- PLATINA*. A fluid ſolution. With difficulty effected, after having been precipitated from aqua-regia by alkalies.
- COPPER. *A green deliqueſcent inflammable ſalt.* By ſolution and inſpiſſating to dryneſs.
- IRON. *Tinctura martis aurea.* By ſolution. The iron is in ſome meaſure rendered volatile by the operation.
- LEAD.
  - A limpid ſolution. By a boiling heat, and frequent cohobations with freſh acid.
  - *Cornea Saturni.* By precipitation from the nitrous acid.
- TIN*.
  - A corroded powder. By ſimple corroſion.
  - *Butter of tin.* By diſtilling from corroſive ſublimate.
- MERCURY*.
  - A colourleſs cryſtalline maſs, extremely acrid. By corroſion, employing the fumes of a very concentrated acid.
  - *Mercur. corroſiv. albus.* By precipitation from the nitrous acid.
  - *Corroſive ſublimate.* By ſubliming from ſal ammoniac, common ſalt, or many other bodies.
  - *Mercurius dulcis.* By reſubliming corroſive ſublimate with more quickſilver.
  - *Mercurial panacea.* By ſubliming corr. ſub. nine times, and digeſting for ſome time in ſpirit of wine.

SEMIMETALS.

- BISMUTH*. A ſolution very ſlightly impregnated. By employing a very concentrated acid.
- ZINC. A ſolution of a very ſlight yellow colour.
- ARSENIC*. *Butter of arſenic.* By diſtilling corroſive ſublimate with arſenic; the arſenic uniting with the acid, and leaving the mercury.
- COBALT. A reddiſh ſolution. By the ordinary means. It becomes green by a gentle heat.
- NICKEL. A green ſolution. By the ordinary means.

OILS*. By ſolution. The union here is but imperfect, nor have they any particular name.

ALCOHOL. *Spiritus ſalis dulcis.* By digeſtion, and afterwards diſtilling. The acid here is never totally dulcified.

WATER. *Acidulated water.* Generating heat by mixture.

V I N E G A R may be combined with the following Subſtances, viz.

ACIDS. VITRIOLIC, NITROUS, and MURIATIC, as in the above table. It likewiſe unites with all other acids, generating heat; but the properties or uſes of theſe are not known.

ALKALIES.

- VEGETABLE. *Regenerated tartar.* By ſolution and cryſtallization.
- FOSSILE. *Polychreſt of Rochelle.* By ditto.
- VOLATILE. *Spiritus Mindereri* By ſolution.

EARTHS.

- CALCAREOUS EARTH. *Earthy ſalts.* Not known in medicine or arts.
- MAGNESIA. *Dr Black's purging ſalt.* By ſolution. It unites with all the other abſorbent earths; but the properties of theſe mixts are unknown.

METALS.

- COPPER. *Verdegris.* By ſolution and cryſtallization; or at large, by ſtratifying copper-plates with the huſks of the grape.
- IRON. *Sal martis aperiens.* By ſolution and cryſtallization.
- LEAD.
  - *Ceruſe.* By expoſing, in certain circumſtances, thin plates of lead to the fumes of vinegar.
  - *Saccharum Saturni.* By ſolution and cryſtallization.
- TIN*. This is not properly diſſolved; but the acid is evidently impregnated. By the ordinary means of ſolution.
- MERCURY*.
  - *A fluid ſolution.* By employing a precipitate of mercury from the nitrous acid by alkalies.
  - *A red calx.* By long digeſtion with fluid mercury.

SEMIMETALS.

- ZINC. A colourleſs ſolution of a ſweetiſh taſte. By digeſting for ſome time.
- ANTIMONY*. *Vinum benedictum.* This it not a proper ſolution of the metal, but the acid is impregnated with an emetic quality.
- ARSENIC. *Vinum arſenicum.* By ditto. A curious phoſphoric liquor.
- BISMUTH. An auſtere ſtyptic liquor. By ſtrong coction.

OILS*. The union here is imperfect, nor have any of them obtained particular names.

ALCOHOL. A mixture much uſed for anointing ſprains, &c.

WATER. *Acidulated water.*

A C I D OF T A R T A R may be combined with the following ſubſtances, viz.

ALKALIES. VEGETABLE.

- Cream of tartar with exceſs of acid.
- Soluble tartar, when completely ſaturated.

ALKALIES.

- FOSSILE. Rochelle ſalt.
- VOLATILE.
  - A ſalt very difficult of ſolution with exceſs of acid.
  - A beautiful and ſoluble ſalt when perfectly ſaturated.

EARTH.

EARTH. Calcareous. An indiſſoluble ſelenite.

METALS.
- Copper. A fine green colour for painting.
- Iron. A green aſtringent liquid. Chalybeated tartar.

SEMIMETAL. Regulus of Antimony. Emetic tartar.

ACID of URINE may be combined with the following ſubſtances, viz.

ACIDS of all kinds. The nature of theſe not known.

ALKALI.
- Fixed Vegetable. A ſalt not eaſily cryſtallized, the nature of which is not known.
- Fossile. A fine cryſtallized ſalt uſed in medicine.
- Volatile. A glaſs-like ſaline ſubſtance called *microcoſmic ſalt.* The acid is always found in this ſtate by evaporating urine.

VITRESCENT EARTHS. A glaſs of different ſorts. By fuſion.

METALS.
- Lead. An inflammable malleable maſs. By calcining the dry ſalt with lead.
- Tin. A maſs reſembling zinc; and inflammable. By ditto.
- Iron. A true *phoſphorus.* By ditto. / A bluiſh ſolution. By employing a watery ſolution of the acid.
- Copper. A corroded powder, or green ſolution. By a boiling heat in a watery ſolution of the acid.
- Mercury. A ſemi-opaque maſs. By fuſion with the acid, in its ſolid form.

SEMIMETALS.
- Zinc. A corroded powder, ſoluble in water. By ſolution in the acid in a watery ſituation. / A true *phoſphorus.* By fuſion with the dry acid.
- Antimony. A ſolution in the ordinary way. / A brilliant ſtriated maſs. By fuſion with the dry acid.
- Bismuth. A mixture but little changed in appearance from ordinary biſmuth. By fuſion.
- Arsenic. A whitiſh ſemitranſparent deliqueſcent maſs. By fuſion.
- Cobalt. A reddiſh tincture. By ſolution.

OILS. *Baldwin's phoſphorus.* By diſtilling with ſubſtances that contain oils or inflammable matter.

FLUOR ACID, may be combined with the following Subſtances, viz.

ALKALIES.
- Fixed Vegetable. A gelatinous ſaline maſs which cannot be cryſtallized. Great part of it is alſo diſſipated by evaporation to dryneſs.
- Fossile. A ſubſtance ſimilar to the foregoing.
- Volatile. Lets fall a quantity of ſiliceous earth, and forms a cryſtallizable ammoniacal ſalt.

EARTHS.
- Lime, Magnesia, Earth of Alum. A gelatinous matter.
- Siliceous Earth. After long ſtanding, cryſtals of quartz.

METALS.
- Silver, Quicksilver. The calces of theſe metals partially diſſolved; but the properties of the ſolution unknown
- Copper. The calx eaſily ſoluble, and affording blue cryſtals; the metal only partially ſo.
- Iron. Diſſolved with violence with the emiſſion of inflammable vapours into an uncryſtallizable liquor.

ACID of SUGAR may be combined with the following Subſtances, viz.

ALKALIES.
- Fixed Vegetable. A ſalt ſcarce capable of cryſtallization when perfectly neutral.
- Fossile. A ſalt difficultly ſoluble in water.
- Volatile. An ammoniacal ſalt ſhooting into quadrangular priſms.

EARTHS.
- Lime. A kind of ſelenite from which the acid cannot be ſeparated by a burning heat.
- Terra Ponderosa. A ſalt formed into angular cryſtals, ſcarce ſoluble in water.
- Magnesia. A white powder inſoluble without an exceſs of acid.
- Earth of Alum. A yellow pellucid maſs incapable of cryſtallization, and liquefying in the air.

METALS.
- Gold, Silver, Platina, Quicksilver. The calces of all theſe metals diſſolved, but the nitre of the ſolutions unknown.
- Iron. Diſſolved in great quantity, and forming a yellow priſmatic ſalt eaſily ſoluble in water.

SEMIMETAL. Cobalt. A yellow-coloured ſalt forming a ſympathetic ink with ſea-ſalt.

INFLAMMABLES. Alcohol. An ether which cannot eaſily be ſet on fire unleſs previouſly heated, and burning with a blue flame.

ACID of BORAX or SEDATIVE SALT may be combined with the following Subſtances, viz.

ALKALIES.
- Fossile. *Borax.* A native ſubſtance, which may be imitated by art. It is of great uſe in promoting the fuſion of metals and earths.
- Volatile. An ammoniacal ſalt ſhooting into ſmall cryſtals, and melting by an intenſe heat into a greyiſh-coloured glaſs.

EARTHS.
- Magnesia. A ſalt cryſtallizable in vinegar and acid of ants. Decompoſed by other acids and ſpirit of wine.
- Earth of Alum. In certain proportions a ſalt difficult of ſolution; in others a hard maſs reſembling pumice-ſtone, yet partially ſoluble in water.

METALS.

METAL.	IRON. An amber-coloured ſolution yielding cryſtals of a yellow colour.
SEMIMETAL.	ARSENIC. A cryſtallizable compound ſhooting into pointed ramifications, or forming a greyiſh, white, or yellow powder.
ALCOHOL.	A ſolution with a conſiderable heat, which burns with a green flame.
WATER.	A ſolution in a conſiderable heat. The other mixtures with this acid not known.

ACID of AMBER may be combined with the following Subſtances, viz.

ALKALIES.	FIXED VEGETABLE. A tranſparent and cryſtallizable ſalt, but deliqueſcent.
	FOSSILE. A cryſtallizable ſalt not deliqueſcent.
	VOLATILE. An ammoniacal ſalt ſhooting into acicular cryſtals.
EARTHS.	LIME. A cryſtallizable ſalt, difficult of ſolution and not deliqueſcent. Decompoſed by common ſal ammoniac.
	MAGNESIA. A gummy deliqueſcent ſaline maſs, not cryſtallizable.
	EARTH of ALUM. A priſmatic ſalt incapable of decompoſition by alkalies.
METALS.	SILVER. A ſalt ſhooting into thin oblong cryſtals obtained from the precipitate; but no ſolution of the perfect metal.
	COPPER. A cryſtallizable ſalt of a green colour.
	IRON. A cryſtallizable ſalt of a brown colour.
	TIN. A cryſtallizable ſalt from the precipitate, ſcarce to be decompoſed by alkalies.
	LEAD. A cryſtallizable ſalt from the precipitate.
SEMIMETALS.	ZINC. A cryſtallizable ſalt.
	BISMUTH. A cryſtallizable ſalt from the precipitate, not to be decompoſed by alkalies.
	REGULUS of ANTIMONY. A ſolution of the precipitate.

ACID of ANTS may be combined with the following Subſtances, viz.

ALKALIES.	FIXED VEGETABLE. A cryſtallizable ſalt, deliqueſcent in the air.
	FOSSILE. A ſalt of a ſimilar nature.
	VOLATILE. An ammoniacal liquor, cryſtallizable with difficulty.
EARTHS.	CHALK or CORAL. A cryſtallizable ſalt which does not deliquate.
	MAGNESIA. A ſaline liquor ſcarcely cryſtallizable.
	TERRA PONDEROSA. A cryſtallizable ſalt which does not deliqueſce.
	EARTH of ALUM. Unites with difficulty, and ſcarcely to the point of ſaturation. The nature of the compound not known.
METALS.	SILVER*. By ſolution. The calx of ſilver precipitated from aquafortis by alkalies; but does not act upon it in its metallic ſtate.
	COPPER. Beautiful green cryſtals. By diſſolving and cryſtallizing calcined copper. It acts ſlowly upon it in its metallic ſtate.
	IRON. A cryſtallizable ſalt. It diſſolves this metal with great facility.
	LEAD*. A ſalt reſembling ſaccharum ſaturni. By diſſolving the red calx of lead. But it does not act upon it in its metallic ſtate.
SEMIMETAL.	ZINC. Elegant cryſtals. By the ordinary means.

The effects of this acid upon other bodies, or the uſes to which theſe combinations might be applied, are not yet ſufficiently known.

ACID of ARSENIC may be combined with the following Subſtances, viz.

ALKALIES.	FIXED VEGETABLE. A ponderous ſalt ſhooting into fine cryſtals by ſuperſaturation with acid.
	FOSSILE. A ſalt cryſtallizable when perfectly neutral.
	VOLATILE. A peculiar kind of ammoniacal ſalt parting with the alkali, and decompoſing ſome of it in a ſtrong fire.
EARTHS.	CHALK. A cryſtallizable ſalt ſcarcely ſoluble.
	MAGNESIA. A gelatinous maſs which cannot be cryſtallized.
	TERRA PONDEROSA. An inſoluble white powder.
METALS.	COPPER. A green-coloured ſolution.
	IRON. A very thick gelatinous ſolution.
	LEAD. A ſolution which cannot be cryſtallized.
	TIN. A gelatinous ſolution in the moiſt way. A mixture taking fire in cloſe veſſels in the dry way.
SEMIMETALS.	ZINC. A ſolution in the moiſt way, and in the dry, a mixture taking fire in cloſe veſſels.
	BISMUTH. A partial ſolution.
	REGULUS of ANTIMONY. A partial ſolution.
	COBALT. A partial ſolution of a red colour.
	MANGANESE. A partial ſolution in its natural ſtate. When the mangaueſe is phlogiſticated, a cryſtallizable ſalt may be obtained.
INFLAMMABLES.	CHARCOAL. A mixture taking fire and ſubliming when heated in cloſe veſſels.
	OIL of TURPENTINE, &c. A thick black ſubſtance after ſome days digeſtion.
	SULPHUR. A red ſublimate.

ALKALIES.

ACID of MOLYBDÆNA may be united with the following Subſtances, viz.

ALKALI.	FIXED VEGETABLE. A cryſtallizable ſalt.
	VOLATILE. A neutral ſalt, the nature of which is unknown.

ACID of MILK may be combined with the following Subſtances, viz.

ALKALIES.	FIXED VEGETABLE. A deliqueſcent ſalt ſoluble in alcohol.
	FOSSILE. A ſalt of a ſimilar nature.
	VOLATILE. A deliqueſcent ſalt parting with much of the alkali by heat.
EARTHS.	CALCAREOUS and ARGILLACEOUS. Deliqueſcent ſalts.
	MAGNESIA. A ſalt more eaſily cryſtallized, but deliqueſcent.
METALS.	COPPER. A blue ſolution, which cannot be cryſtallized.
	IRON. A brown ſolution, with the emiſſion of inflammable air, yielding no cryſtals.
	LEAD. An aſtringent ſweetiſh ſolution, which does not cryſtallize.
SEMIMETAL.	ZINC. A cryſtallizable ſalt, with the emiſſion of inflammable air during the ſolution.

ACID of SUGAR of MILK may be combined with the following Subſtances, viz.

ALKALIES.	FIXED VEGETABLE. A ſalt very difficult of ſolution.
	FOSSILE. A ſalt more eaſily ſoluble.
	VOLATILE. A peculiar kind of ammoniac.
EARTHS.	ABSORBENT and ARGILLACEOUS. Inſoluble ſalts.

ACID of APPLES may be combined with the following Subſtances, viz.

ALKALIES.	FIXED VEGETABLE, FOSSILE, and VOLATILE. Deliqueſcent ſalts.
EARTHS.	CALCAREOUS. A ſalt difficult of ſolution unleſs the acid prevail.
	MAGNESIA. A deliqueſcent ſalt.
	EARTH of ALUM. A ſalt very difficult of ſolution.
METAL.	IRON. A brown ſolution, which does not cryſtallize.
SEMIMETAL.	ZINC. A fine cryſtallizable ſalt.

ACID of FAT may be combined with the following Subſtances, viz.

ALKALIES.	FIXED, VEGETABLE, and FOSSILE. Neutral ſalts of a particular nature.
	VOLATILE. A concrete volatile ſalt.
EARTHS.	CALCAREOUS. A cryſtallizable ſalt of a brown colour.
	MAGNESIA. EARTH of ALUM. A gummy maſs, which refuſes to cryſtallize.
METALS.	SILVER. A ſolution of the calx.
	PLATINA. The calx copiouſly diſſolved, and even the perfect metal attacked by diſtillation to dryneſs.
	COPPER. A green ſolution, which cannot be cryſtallized.
	IRON. A cryſtallizable ſalt, which does not deliquate.
	LEAD. An aſtringent ſolution of the red calx called *minium*.
	TIN. A ſolution in ſmall quantity.
	MERCURY. A ſolution by being twice diſtilled from the metal.
SEMIMETALS.	ZINC. Diſſolved in its metalline ſtate.
	BISMUTH. A ſolution of precipitate.
	REGULUS of ANTIMONY. A cryſtallizable ſalt, which does not deliquate.
	MANGANESE. A perfect and clear ſolution.

ACID of BENZOIN may be combined with the following Subſtances, viz.

ALKALIES.	FIXED VEGETABLE. A ſalt ſhooting into pointed feathery cryſtals.
	FOSSILE. A ſalt procurable in larger cryſtals.
	VOLATILE. A deliqueſcent ſalt ſcarce cryſtallizable.
EARTHS.	CALCAREOUS. A cryſtallizable ſalt not eaſily ſoluble.
	MAGNESIA. A cryſtallizable ſalt eaſily ſoluble.

The FIXED ALKALI, whether VEGETABLE or FOSSILE, can be united with the following Bodies; but the Vegetable is beſt known.

ACIDS:	Vitriolic, Nitrous, Muriatic, Vegetable; and acid of Urine, of Amber, of Ants, of Borax, &c. as in the former part of this Table.
ALKALIES	of all ſorts. The uſes of theſe mixtures are not known.
EARTHS.	CRYSTALLINE. *Liquor ſilicum.* By fuſion with twice their weight of alkali. *Glaſs.* By fuſion with a much ſmaller proportion of alkali. This is the compoſition of cryſtal glaſs, and all others commonly uſed.
	ABSORBENTS. Argillaceous, and all kinds of earths. *Glaſs.* By fuſion; differing in quality according to the nature of the ingredients. Glaſs is likwiſe produced with it in fuſion with metals.
METALS.	GOLD*. After having precipitated it from aqua-regia, it diſſolves it if the alkali has been calcined with animal ſubſtances.
	SILVER*. After having precipitated it from the nitrous acid, it diſſolves it if the alkali has been calcined in contact with the flame.

METALS.

METALS.
- Tin. A corroded powder. By the ordinary means of ſolution.
- Copper. By ditto.
- Lead. A fluid ſolution. By ditto. This ſtains hair black.
- Iron*. A blood-coloured ſolution. By dropping a ſolution of iron in the nitrous acid, into an alkaline lixivium.
- Mercury*. A fluid ſolution. After precipitating it from acids; if the alkali is in too large proportions, it then diſſolves it, eſpecially if the alkali has been calcined in contact with the flame.

SEMIMETALS.
- Zinc*. By ſolution, after having precipitated it from the nitrous acid.
- Bismuth*. By ſolution, after having precipitated it from the nitrous acid.
- Antimony.
  - *Kermes mineral.* By diſſolving antimony in an alkaline lixivium, filtering, and allowing it to ſtand in a cool place till it precipitates.
  - *Golden ſulphur of antimony.* By diſſolving a crude antimony in an alkaline lixivium, and precipitating by an acid.
  - *Hepar antimonii.* By deflagrating crude antimony with nitre.
  - *Crocus metallorum.* Is hepar antimonii pulveriſed and edulcorated with water.
  - *Diaphoretic antimony.* By deflagrating regulus of antimony with nitre.
  - *Antimoniated nitre.* By diſſolving diaphoretic antimony in water, and allowing it to cryſtallize.
  - *Magiſtery of antimony.* By precipitating a ſolution of diaphoretic antimony by adding vinegar.
  - *Regulus antimonii medicinalis.* By fuſing crude antimony with alkali. This is not properly a compound of alkali and antimony, but of another kind. But as it is a term much uſed, it was proper to explain it.
- Arsenic*. A metallic arſenical ſalt. By a particular elective attraction from regulus of antimony and nitre.

OILS.
- Expressed. *Soap.* The beſt hard ſoap is made of olive-oil and foſſile alkali. The ordinary white ſoap of this country is made of tallow and potaſh; black ſoap with whale-oil and potaſh.
- Essential. *Saponaceous maſs.* Beſt made by pouring ſpirit of wine upon cauſtic alkali and then oil, digeſting and ſhaking.
- Empyreumatic. This mixture diſſolves gold when precipitated from aqua regia; and is the baſis of the fine colour called *Pruſſian blue;* and has various other properties, as yet but little known.
- Fossile. This has no name, nor are the properties well known; but from ſome obſervations that have been made on native ſoapy waters, it is probable that it would keep linen much longer white than any other kind of ſoap.

SULPHUR.
- *Hepar ſulphuris.* By injecting alkalies upon melted ſulphur.
- *Lac ſulphuris.* By diſſolving ſulphur in an alkaline lixivium, and precipitating by an acid.

WATER. *Alkaline lixivium,* when cauſtic, or even the ordinary ſolution of mild alkali, is a fluid of great power in waſhing, bleaching, &c.

AIR. Fixed. *Mild alkali.* This is the general ſtate in which alkalies are found; but if they are rendered cauſtic by means of quick-lime or otherwiſe, they again abſorb it from the air, or from many other bodies, by elective attraction. When perfectly mild, this alkali may be made to aſſume a cryſtalline form.

The VOLATILE ALKALI, or SPIRIT OF SAL AMMONIAC, can be united with theſe Bodies, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable; of Urine, of Amber, of Ants, &c.

ALKALI, as above.

METALS.
- Gold*.
  - *Aurum fulminans.* A powder obtained by precipitating it from aqua regia by volatile alkalies.
  - A liquid ſolution. By adding a large proportion of alkali after it has been precipitated from aqua regia. This depoſites the gold when long expoſed to the air. The curious vegetation called *arbor Dianæ* is formed by adding mercury to this ſolution. A violently fulminating powder obtained by digeſtion.
- Silver*. A ſolution. After it has been precipitated from the nitrous acid. A fulminating powder by digeſtion.
- Platina*. By ſolution, after having precipitated it from aqua regia.
- Copper.
  - A blue-coloured ſolution. By the ordinary means. This when evaporated to dryneſs, and mixed with tallow, tinges the flame green.
  - Sapphire-coloured cryſtals. By cryſtallizing the ſolution.
  - *Venus fulminans.* By evaporating the ſolution to dryneſs.
  - *Aqua cerulea ſapphirina.* By mixing ſal ammoniac, quick-lime, and thin plates of copper, with water, and allowing them to remain a night.
- Iron. By ordinary ſolution.
- Lead. By ditto.
- Tin. The mixts that are produced by theſe metals are little known.

SEMIMETALS.
- Bismuth*. By ſolution, after having precipitated it from the nitrous acid.
- Antimony.
- Cobalt. A reddiſh liquor. By ſolution.
- Nickel. A blue liquor. By ditto.

OILS.
- Expressed. Has no name. By ſolution.
- Essential. *Sal volatile oleoſum.* By ditto with ſome difficulty, unleſs the alkali is in a cauſtic ſtate.
- Empyreumatic. A pungent oily ſubſtance, of great power in medicine. The principal one of this kind in uſe is ſpirit of hartſhorn.
- Fossile. A particular kind of ſoapy ſubſtance.

SULPHUR. Smoking ſpirit of ſulphur. By diſtilling ſal ammoniac, quick-lime, and ſulphur.
ALCOHOL*. By diſtilling alcohol from volatile alkalies, it acquires a cauſtic fiery taſte ; but the union is not complete.
WATER. This ſolution might be of uſe in waſhing or bleaching ; but, unleſs in particular caſes, would be too expenſive. It coagulates with alcohol.
AIR. Fixed Mild volatile alkali. The uſual ſtate in which it is found ; nor has any method yet been diſcovered of rendering it ſolid but in this ſtate.

EXPRESSED OILS may be combined with the following Subſtances, viz.

ACIDS : Vitriolic, Nitrous, Muriatic, Vegetable, of Urine, of Amber, as in the foregoing part of this Table.
ALKALIES : Fixed and Volatile, as above.
CALCAREOUS EARTHS. A kind of plaſter. By mixture when in a cauſtic ſtate.
METALS.
- Tin*. Ditto. By ſolution when the tin is in the ſtate of a calx.
- Lead*. Ditto. By boiling the calx of lead in oils. This is uſed for cements in water-works. The common white paint is a mixture of this leſs perfect.

SEMIMETALS. Zinc*. Ditto. By ditto.
OILS : Eſſential, Empyreumatic, and Foſſile. By mixture but their uſes are not much known.
SULPHUR, *Balſam of Sulphur.* By ſolution in a boiling heat.
ALCOHOL. After expreſſed oils are freed from ſoap or plaſters, they are ſoluble in alcohol ; but not in their ordinary ſtate.

ESSENTIAL OILS may be combined with the following Subſtances, viz.

ACIDS : Vitriolic, Nitrous, &c. as above.
ALKALIES : Fixed and Volatile, as above.
METALS.
- Copper. By ſolution.
- Lead. By ditto.

OILS of all kinds. By ſolution or mixture.
SULPHUR. A balſam of ſulphur. By ſolution, imperfectly ; better by adding eſſential oils to the ſolution made by expreſſed oils or hepar ſulphuris.
ALCOHOL.
- Imperfect mixture. By ſolution.
- Aromatic waters. By diſtillation.

WATER. Diſtilled water of the ſhops. By diſtilling recent vegetable ſubſtances with water.

EMPYREUMATIC OILS may be combined with the following Subſtances, viz.

ACIDS : Vitriolic and Nitrous, as above.
ALKALIES : Fixed and Volatile, as above.
OILS of all kinds. By mixture.
ALCOHOL. By ſolution. By repeated diſtillations the oils are rendered much more ſubtile.

FOSSILE OILS may be combined with the following Subſtances, viz.

ACIDS : Vitriolic and Nitrous, as above.
ALKALIES : Fixed and Volatile, as above.
OILS of all kinds. By mixture.
SULPHUR. With ſome difficulty, by ſolution.
ALCOHOL. - - - By ditto.

SULPHUR may be combined with the following, Subſtances, viz.

ACID* : Vitriolic ; with the phenomena above deſcribed.
ALKALIES : Fixed and Volatile, as above.
METALS.
- Silver. A maſs of red-like colour. By adding ſulphur to red-hot ſilver, and fuſing ; found alſo with it in the ſtate of an ore.
- Lead. A ſparkling friable maſs, hardly fuſible. By deflagrating ſulphur with lead. This in a native ſtate forms the ore of lead called *galena*.
- Copper. A Black brittle maſs, eaſily fuſed. By adding ſulphur to red-hot copper, or ſtratifying with ſulphur and fuſing. Naturally in ſome yellow pyrites.
- Iron.
  - A ſpungy-like droſs, eaſily fuſible. By putting ſulphur to red-hot iron. This is alſo found naturally in the common yellow or brown pyrites.
  - A fulminating compound. By mixing filings of iron with ſulphur, moiſtening them with water, and preſſing them hard, they in a few hours burſt out into flame. This compoſition has been employed for imitating earthquakes.
  - *Crocus martis.* By deflagrating with iron.
  - *Crocus martis aperiens.* By calcining the crocus martis in the fire till it aſſumes a red appearance.
  - *Crocus martis aſtringens.* By puſhing the heat ſtill further.
- Tin. A dark-coloured maſs, reſembling antimony. By fuſion.
- Mercury.
  - *Ethiops mineral.* By heating flowers of ſulphur, and pouring the mercury upon it, and ſtirring it well. Its natural ore is called *cinnabar*.
  - *Factitious cinnabar.* By applying the mercury and ſulphur to each other in their pure ſtate, and ſubliming.
  - *Cinnabar of antimony.* By ſubliming corroſive ſublimate and crude antimony ; or the reſiduum, after diſtilling butter of antimony.

SEMIMETALS.

SEMIMETALS.
- BISMUTH. A faint greyiſh maſs, reſembling antimony. By fuſion. If in its metalline ſtate, the ſulphur ſeparates in the cold; but not ſo if the calx has been employed.
- ANTIMONY. *Crude antimony.* By fuſion.
- ZINC*. A very brittle, dark-coloured, ſhining ſubſtance. With ſome difficulty, by keeping it long in a moderate fire, and covering it ſeveral times with ſulphur, and keeping it conſtantly ſtirred.
- ARSENIC.
  - *Yellow arſenic.* By fuſing it with $\frac{1}{10}$th its weight of ſulphur.
  - *Red arſenic.* By ditto with $\frac{1}{5}$th its weight of ſulphur.
  - *Ruby of ſulphur*, or arſenic, or golden ſulphur. By ſubliming when the proportions are equal.
  - *Orpiment.* A natural production; not perfectly imitable by art; compoſed of ſulphur and arſenic. Much uſed as a yellow paint.
- NICKEL. A compound; compact and hard as lead; of a bright metallic appearance; internally yellow. By fuſion.

OILS: Expreſſed, Eſſential, and Foſſile, as above.
WATER. *Gas ſylveſtre.* By receiving the fumes of burning ſulphur in water. This ought rather to be called a union of the volatile vitriolic acid with water.

ALCOHOL may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, and of Borax, as above.
ALKALI*: Volatile, as above.
METALLIC calces, in ſome particular caſes.
OILS: Expreſſed, Eſſential, Empyreumatic, and Foſſile, as above.
WATER. By ſolution.

GOLD may be combined with the following Subſtances, viz.

ACIDS: Vitriolic*, Nitrous*, and Muriatic*. In the circumſtances and with the phenomena above deſcribed.
ALKALIES: Fixed*, and Volatile*, as above.

METALS.
- SILVER. By fuſion. And the ſame is to be underſtood of all the combinations of metals, unleſs particularly ſpecified.
- PLATINA. Ductile, and of a duſky colour. This has been employed to debaſe gold, as it is of the ſame ſpecific gravity, and is not diſcoverable by the uſual teſts for diſcovering the purity of gold.
- LEAD. A very brittle maſs. Gold is rendered pale by the leaſt admixture with this.
- TIN. A brittle maſs when the tin is added in conſiderable quantity; but the former accounts of this have been exaggerated.
- COPPER. Paler and harder than pure gold. This mixture is uſed in all our coins, the copper being called the *alloy*.
- IRON. Silver-coloured, hard and brittle; very eaſily fuſed.
- MERCURY. Soft like a paſte called an *amalgamum.* By ſolution; it being in this caſe called *amalgamation*; and the ſame is to be underſtood of the ſolution of any other metal in quickſilver.

SEMIMETALS.
- ZINC. A bright and whitiſh compound, admitting of a fine poliſh, and not ſubject to tarniſh; for which qualities it has been propoſed as proper for analyſing ſpecula for teleſcopes.
- ARSENIC. Brittle; and the gold is thus rendered a little volatile.
- ANTIMONY. A fine powder for ſtaining glaſs of a red colour. By calcination.
- BISMUTH*. A brittle whitiſh regulus; volatile in the fire.
- COBALT.
- NICKEL. White and brittle.

SILVER may be combined with the following Subſtances, viz.

ACIDS: Vitriolic*, Nitrous*, Muriatic*, Vegetable*, and Acid of Ants*, as above.
ALKALIES: Fixed* and Volatile*, as above.
CRYSTALLINE EARTHS and other vitreous matters. A fine yellow opake glaſs. The fineſt yellow paint for porcelain is procured from glaſs mixed with ſilver.

METALS.
- GOLD, as above.
- PLATINA. Pretty pure and malleable. Difficult of fuſion; and in part ſeparates when cold.
- LEAD. Very brittle.
- TIN. Extremely brittle, as much ſo as glaſs.
- COPPER. Harder than ſilver alone. Uſed in ſmall proportions as alloy in coins.
- IRON. A hard whitiſh compound.
- MERCURY*. By amalgamation with ſilver-leaf, or calx of ſilver precipitated by copper, but not by ſalts. This is uſed for ſilverizing on other metals, in the ſame way as the amalgamum of gold.

SEMIMETALS.
- ZINC. Hard, ſomewhat malleable, and of a white colour.
- ANTIMONY. A brittle maſs.
- BISMUTH. A white ſemi-malleable body.
- ARSENIC. Brittle; the ſilver being rendered in part volatile.
- COBALT.

SULPHUR, as above.

LEAD may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, of Urine, of Ants, as above.
ALKALIES: Fixed and Volatile, as above.

CRYSTALLINE EARTHS. A thin glafs. By fufion in a moderate heat.

METALS.
- Gold and Silver, as above.
- Platina. Of a leafy or fibrous texture, and purplifh or blue colour when expofed to the air. If a large proportion of platina is ufed, it feparates in the cold.
- Tin. A little harder than either of the metals, and eafily fufed: hence it is ufed as a folder for lead; and it forms the principal ingredients of pewter. If the fire is long continued, the tin floats on the furface.
- Copper*. Brittle and granulated, like tempered iron or fteel when broke. By throwing pieces of copper into melted lead. The union here is very flight.
- Iron*. An opaque brownifh glafs. By a great degree of heat if the iron has been previoufly reduced to the ftate of a calx; but never in its metallic ftate.
- Mercury*. By amalgamation. Effected only in a melting heat, unlefs fome bifmuth has been previoufly united with the mercury.

SEMIMETALS.
- Zinc. Hard and brittle. By pouring zinc on melted lead. If the zinc is firft melted, and the lead injected upon it, it then deflagrates.
- Antimony*.
- Bismuth. A grey-coloured femi-malleable body, eafily fufed; and thence ufed as a folder for lead or tin.
- Arsenic.
  - A grey-coloured brittle mafs, eafily fufed, and extremely volatile.
  - A hyacinth-coloured glafs. By fufion in a confiderable heat. This glafs is eafily fufed; and is a much more powerful flux than pure glafs of lead.
- Cobalt. The nature of this compound is not known.
- Nickel. A brittle metallic body.

OILS: Expreffed* and Effential, as above.

SULPHUR, as above.

TIN may be combined with the following Subftances, viz.

ACIDS: Vitriolic*, Nitrous*, Muriatic, Vegetable*, of Urine, as above.

ALKALIES: Fixed and Volatile, as above.

CRYSTALLINE EARTHS or other vitreous matters. An opaque white vitreous mafs, which forms the bafis of white enamels.

METALS.
- Gold, Silver, and Lead, as above.
- Platina. A coarfe hard metal which tarnifhes in the air.
- Copper. A brittle mafs. When the copper is in fmall proportions, it is firmer and harder than pure tin. This, in right proportions with a little zinc, forms bell-metal.
- Iron. A white brittle compound. By heating filings of iron red-hot, and pouring melted tin upon them. A metal refembling the fineft filver is made of iron, tin, and a certain proportion of arfenic.
- Mercury. This amalgamum forms foils for mirrors; and forms the yellow pigment called *aurum mofaicum*. By being fublimed with fulphur and fal ammoniac.

SEMIMETALS.
- Zinc. Hard and brittle. When the zinc is in fmall proportions, it forms a very fine kind of pewter.
- Antimony* *Regulus veneris*. By elective attraction from copper and crude antimony.
- Bismuth. Bright, hard, and fonorous, when a fmall proportion of bifmuth is ufed. This is very eafily fufed, and employed as a folder.
- Arsenic. A fubftance in external appearance refembling zinc.
- Cobalt. By fufion.
- Nickel. A brittle metallic mafs.

OIL: Expreffed*, as above.

SULPHUR, as above.

COPPER may be combined with the following Subftances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, of Urine, of Amber, of Ants, as above.

ALKALIES: Fixed, and Volatile, as above.

METALS.
- Gold, Silver, Lead*, and Tin, as above.
- Platina. A white and hard compound, which does not tarnifh fo foon as pure copper, and admits of a fine polifh.
- Iron. Harder and paler than copper. Eafily fufed.
- Mercury*. A curious amalgam. Soft at firft, but afterwards brittle. By triturating mercury with verdigris, common falt, vinegar, and water.

SEMIMETALS.
- Zinc.
  - *Brafs*. Commonly made by cementation with calamine. The larger the proportion of zinc, the paler, harder, and more brittle is the brafs.
  - *Prince's metal, pinchbeck*, and other metals refembling gold. By employing zinc in fubftance in fmall proportions. The beft pinchbeck about 1-4th of zinc.
  - *Spelter*. A native fubftance, found in Cornwall, confifting of zinc and copper, and ufed as a folder.
- Antimony. By fufion.
- Bismuth. A palifh brittle mafs. Somewhat refembling filver.
- Arsenic. *White copper*. By pouring arfenic, fufed with nitre, upon copper in fufion. If too large a proportion of arfenic is ufed, it makes the compound black and apt to tarnifh.
- Cobalt. White and brittle.
- Nickel. White and brittle, and apt to tarnifh.

OILS: Effential, as above.

SULPHUR, as above.

IRON

IRON may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, of Urine, of Amber, of Ants, as above.
ALKALIES: Fixed*, and Volatile, as above.
VITRESCENT EARTHS. A tranſparent glaſs. In general blackiſh; but ſometimes yellow, green, or blue. The colour is influenced by the degree of heat as well as nature of the ingredients.

METALS.
- GOLD, Silver*, Lead*, Tin, and Copper, as above.
- PLATINA. With caſt iron it forms a compound remarkably hard, ſomewhat ductile, and ſuſceptible of a fine poliſh.

SEMIMETALS.
- ZINC. A white ſubſtance reſembling ſilver.
- ANTIMONY. The magnetic quality of the iron is totally deſtroyed in this compound.
- BISMUTH. In a ſtrong heat, this emitteth flames.
- ARSENIC. A whitiſh, hard, and brittle compound. By fuſing with ſoap or tartar. A metal reſembling fine ſteel is made by fuſing caſt iron with a little arſenic and glaſs.
- COBALT. A compound remarkably ductile. By fuſion in a moderate heat.
- NICKEL. A brittle maſs.

SULPHUR, as above.

MERCURY may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrious, Muriatic, Vegetable*, of Urine, as above.
ALKALI: Fixed*, as above.

METALS.
- GOLD, Silver*, Lead*, Tin, and Copper, as above.
- PLATINA. The compound reſulting from this mixture is not known.

SEMIMETALS.
- ZINC. An amalgam. Soft or hard, according to the proportions employed.
- ANTIMONY. By melting the regulus, and pouring it upon boiling mercury. By frequently diſtilling from this amalgam, the mercury is rendered much more pure, and then is called *animated mercury*.
- BISMUTH. A ſilverizing for iron. By putting this amalgam upon iron, and evaporating the mercury. It has much the appearance of ſilver.
- COBALT. By mixing firſt with nickel, and then adding mercury.

SULPHUR, as above.

ZINC may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, of Urine, of Amber, of Ants, as above.

METALS.
- GOLD, Silver, Lead, Tin, Copper, and Iron, as above.
- PLATINA A hard ſubſtance.
- MERCURY, as above.

SEMIMETALS.
- ANTIMONY. This mixture is applied to no particular uſe.
- ARSENIC. A black and friable maſs.
- COBALT. The particular nature and properties of this mixt is not known.

OIL: Expreſſed*, as above.
SULPHUR*, as above.

ANTIMONY may be combined with the following Subſtances, viz.

ACIDS: Vitriolic*, Nitrous, Vegetable*, and Urinous. With the phenomena, and by the means above deſcribed.
ALKALIES: Fixed and Volatile, as above.
VITREOUS EARTHS. A thin penetrating glaſs; which is a powerful flux of metals.

METALS.
- GOLD, Silver, Lead, Tin*, Copper, and Iron, as above.
- PTATINA. A hard maſs.
- MERCURY, and Zinc, as above.

SEMIMETALS.
- BISMUTH. A maſs reſembling regulus of Antimony.
- ARSENIC. The nature and qualities of this mixt are not known.
- COBALT. Nature unknown.
- NICKEL. Ditto.

SULPHUR, as above.

BISMUTH may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, and Urinous; with the phenomena, *&c.* above deſcribed.
ALKALIES: Fixed*, and Volatile*, as above.
VITREOUS MATTERS. A yellow glaſs. The ore of Biſmuth affords with theſe a blue glaſs; but this is probably owing to ſome mixture of Cobalt with it.

METALS.
- GOLD, Silver, Lead, Tin, Copper, and Iron, as above.
- PLATINA. This mixture changes its colour much on being expoſed to the air.
- MERCURY, as above.

SEMIMETALS.
- ANTIMONY, as above.
- ARSENIC. Nature not known
- COBALT*. By mixing firſt with with nickel or regulus of antimony, and then adding cobalt; but it cannot be united by itſelf.
- NICKEL. This mixt is not known.

SULPHUR, as above.

ARSENIC may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Muriatic*, Vegetable*, and Urinous; with the phenomena, *&c.* abovementioned.

ALKALIES.

ALKALIES : Fixed, and Volatile ; with the phenomena, and by the means mentioned above.
VITREOUS MATTERS. A glafs which greatly promotes the fufion of other fubftances. The arfenic muft firft be prepared by diffolving and precipitating from alkalies.
METALS. { GOLD, Silver, Lead, Tin, Copper, and Iron, as above.
PLATINA.
SEMIMETALS. { ZINC, Antimony, and Bifmuth, as above.
COBALT.
NICKEL. The phenomena attending thefe mixtures have not been as yet particularly obferved.
SULPHUR, as above.

PLATINA may be combined with the following Subftances, viz.
ACIDS : Muriatic*; with the phenomena, *&c.* mentioned above.
ALKALI : Volatile, as above.
METALS : GOLD, Silver, Mercury, Tin, Copper, and Iron, as above.
SEMIMETALS. { ZINC, Bifmuth, and Arfenic, as above.
COBALT.
NICKEL. The phenomena attending thefe mixtures not yet obferved.

COBALT may be combined with the following Subftances, viz.
ACIDS : Vitriolic, Nitrous, Muriatic, and Urinous ; with the phenomena, *&c.* as above defcribed.
ALKALI : Volatile, as above.
EARTHS. CALX of FLINT. { *Saffre.* By mixing calcined cobalt with calx of flint, and moiftening them with water, and preffing them clofe in wooden tubs.
Smalt. By vitrifying thefe with the addition of a little potafh.
METALS : GOLD, Silver, Platina, Mercury*, Lead, Tin, Copper, and Iron, as above.
SEMIMETALS. { ZINC, Antimony, Bifmuth*, and Arfenic, as above.
NICKEL. The properties of this compound not known.

NICKEL may be combined with the following Subftances, viz.
ACIDS : Nitrous, and Muriatic ; with the phenomena, *&c.* as mentioned above.
ALKALI : Volatile, as above.
METALS : Gold, Platina, Lead, Tin, Copper, and Iron, as above.
SEMIMETALS : Antimony, Bifmuth, Arfenic, and Cobalt, as above.
SULPHUR, as above.

ABSORBENT EARTHS may be combined with the following Subftances, viz.
ACIDS : Vitriolic, Nitrous, Muriatic, and Vegetable ; with the phenomena, and by the affiftances abovementioned.
ALKALIES : Fixed as above.
EARTHS. { CRYSTALINE. By this mixture they are both much eafier melted into glafs than by themfelves, but not without the addition of fome alkali.
ARGILLACEOUS. This mixture eafily runs into a glafs without any addition.
WATER. *Lime-water.* By folution. It is fometimes found flowing out of the earth in fprings ; and as it always quits the water when expofed to the air, it is there depofed on the banks of the ftreams, forming the ftony incruftations called *petrifications :* And filtering through the pores of the earth, and dropping through the roofs of fubterraneous caves, it forms the curious incruftations found hanging from the roof of fuch places ; fometimes affuming forms ftupenduoufly magnificent.
AIR. FIXT. *Lime-ftone.* It is from the quality that quick-lime has of abforbing its air, again with it refuming its ftony confiftence, that it is fitted for a cement in building ; and the great hardnefs of the cements in old buildings is owing to the air being more perfectly united with thefe than in newer works.

CRYSTALLINE or VITRESCENT EARTHS may be combined with the following Subftances, viz.
ACIDS : Vitriolic*, and Nitrous*; with the phenomena, *&c.* as abovementioned.
ALKALI : Fixed, as above.
ABSORBENT EARTHS : as above.
ARGILLACEOUS EARTHS. A mafs running into glafs in a moderate heat.
METALS : Lead, Tin, Copper, and Iron, as above.
WATER. Although this is not foluble in water by any operation that we are acquainted with ; yet, from its cryftalline form, it is probable that it has been once fufpended ; and certainly it is fo at this day in thofe petrifying fprings whofe incruftations are of the cryftalline fort.
SEMIMETALS : Antimony, Bifmuth, Arfenic, and Cobalt, as above.

ARGILLACEOUS EARTH may be combined with Abforbent and Cryftalline Earths, as above. With water it only unites into a pafte of a mechanical nature.

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Weigleb's

Some late experiments of Dr Priestley, have shown, that though nitrous acid is produced from the decomposition of dephlogisticated and phlogisticated air, by taking the electric spark in the mixture, it is likewise produced by the more rapid decomposition of combustion, when inflammable air is made use of instead of the phlogisticated kind. In this case, though phlogisticated air should happen to exist in the mixture, it is not in the least affected by the process, but remains after the combustion of the others, just as it was; nay, the Doctor observes, that by the addition of phlogisticated air, the quantity of nitrous acid produced is so far from being augmented, that it is much diminished. The acid in these processes always appears to be extremely volatile, insomuch that some part of it constantly escapes. No liquor at all was condensed when the explosions were made in quick succession, even though the vessel never became hotter than the hand. In another process, the atmospheric air was perfectly excluded, while the purest dephlogisticated air was produced from one of the materials employed, viz. precipitate *per se*. In this experiment he found, that a considerable quantity of fixed air was produced, and that the water became acid by the absorption of it. He concludes, therefore, on the whole, that a mixture of dephlogisticated and inflammable air always produces an acid by combustion; but that, when they are in their nascent state, the aerial acid is generated; when both are completely formed previous to the experiment, the nitrous acid appears.

M. Pelletier has now discovered a method of uniting phosphorus, without any decomposition, with all the metals, though he cautions against the danger with which the process is attended. Gold is phosphorated by mixing half an ounce of its calx with an ounce of phosphoric glass and about a grain of powdered charcoal; the whole is then put into a crucible, the composition covered with a little powdered charcoal, and a degree of heat sufficient to fuse the gold applied. A great many phosphoric vapours arise, but part are detained, and unite with the gold which is left at the bottom of the crucible. The metal by this operation loses its colour, becomes whitish, breaks under the hammer, and has a crystalline appearance. By continuing the fire a long time the phosphorus would be entirely dissipated. The quantity of phosphoric glass and charcoal just mentioned is sufficient to phosphorate a whole ounce of platina. By an hour's calcination in a crucible, the metal is converted into a blackish mass resembling silver, weighing upwards of an ounce, and of which the lower part consists of cubical crystals. Notwithstanding this change, however, the quantity of phosphorus united with the platina is very inconsiderable; for from 12 ounces of the metal, and as much phosphoric glass, only 12 ounces and five grains of the phosphorated metallic mass was obtained. It was very brittle, but of considerable hardness; was not attracted by the magnet, and by exposure to a strong fire parted with the phosphorus it had been combined with. He observes, that all the metals lose their malleability by combination with phosphorus, excepting tin and lead; and the residuum of the matter which has once phosphorated a metal, will serve again for the same purpose.

The

Though the acid of tartar has been commonly supposed a product of the vinous fermentation, yet late experiments have shown that this is not the case. It has been found not only in the juice of the grape, but in that of tamarinds, the berries of the *rhus coriaria*, and the leaves of the *rumex acetosa*. In these it is generally combined with the vegetable fixed alkali, or with calcareous earth. Hermbstadt has found it combined with calcareous earth in the juice of the roots of the *triticum repens*, the *leontodon taraxacum*, and *China bark*. By the assistance of nitrous acid he obtained it also from the juice of grapes, mulberries, apples, pears, oranges, strawberries, and plums; also from honey, sugar, gum arabic, manna, spirit of wine, beech-wood, and the root of black hellebore. In these cases, where the nitrous acid is made use of, however, it may justly be supposed that the acid of tartar is partly at least produced from it. In Scheele's process for procuring the pure acid of tartar by means of calcareous earth, it is advisable to make use of quicklime rather than chalk, as by this double the quantity of tartar will be decomposed. An hundred parts of pure tartar contain about 23 of vegetable alkali, 43 parts of acid employed to saturate that alkali, and 34 of superabundant acid. By using oyster-shells well prepared by boiling and powdering, the crystals of the acid may be obtained very white and pure. Some chemists have imagined that the vegetable alkali does not exist ready formed in tartar, but that it is produced by fire or mineral acids. In proof of this M. Machi offers the following experiments. On an ounce of cream of tartar were poured 10 ounces of boiling water, and the mixture allowed to remain in a jar covered with paper and parchment in which a small hole was made with a pin. At the end of three months it was considerably diminished; and contained a quantity of thick, tough, yellow, mucilaginous matter, which neither effervesced with acids nor alkalies, and, when burnt, the ashes were found to contain only a very small quantity of alkali. The experiment was repeated by Mr Corvinus with some variation. He kept a solution of cream of tartar in a heat between 10° and 30° of Reaumur's scale; removing the saline pellicles which formed on the surface as fast as they appeared, and redissolving them in water. By continuing the digestion for several months, the liquor became at last evidently alkaline: and he thus obtained 216 grains of a brown alkali from two ounces of cream of tartar. Mr Berthollet exposed for nine months, to the heat of his laboratory, a solution of two ounces of cream of tartar in eight ounces of water; taking care to replace the water which evaporated, but without removing the crusts which formed upon the surface. At the end of this time he found that the liquor was no longer acid, but began to turn the syrup of violets green. In 18 months it became strongly alkaline; and left, when evaporated, an oily residuum which effervesced with acids, and weighed 468 grains. On treating in the same manner a solution of terra foliata tartari, the liquor began to change the syrup of violets green in two months, and in four the decomposition seemed to be complete. At the end of a year he filtered and evaporated the liquor to dryness, by which process he obtained 432 grains of fixed alkali. The same quantity of terra foliata tartari decomposed immediately by distillation, yielded only 36 grains more of alkali. Solution of salt of wood-sorrel suffered no decomposition by a similar treatment for two years. The latter he observed to be a much more powerful antiseptic than tartar; for which reason it seems to resist decomposition in a proportionable degree. He supposes oil to be the principal cause of the destruction of these acids; and the obvious deficiency of oil in the saccharine acid, in comparison with tartar, seems to be the cause of the want of capacity in it to undergo the decomposition just mentioned. A remarkable circumstance attends this spontaneous decomposition, viz. that no air is either absorbed or emitted during the whole process. It is also worth notice, that in combining acid of tartar with fixed alkalies, the salt supersaturated with acid or cream of tartar is always formed in preference to the other called *soluble tartar.* Thus if to a saturated solution of alkali with cream of tartar we add another of pure tartareous acid, a white spongy matter will be precipitated to the bottom; which, on examination, is found to be a true tartar. Any other acid added to the solution of tartarised tartar will in like manner produce a precipitation of tartar, by engaging a part of the alkali with which it was combined; and if the acid of tartar be added to a solution of any neutral salt containing the vegetable fixed alkali, as vitriolated tartar, salt of Sylvius, and nitre, a similar precipitation of tartar will ensue. Hence the acid of tartar may be employed as a test to discover the presence of the vegetable fixed alkali, and to distinguish it from the mineral, which has not that effect. Bergman indeed observes, that Rochelle salt will do the same thing; but it must be remembered that this is prepared with crude tartar, which contains a portion of vegetable alkali, and not with the pure acid.

Dobson, Thomas, *A system of chemistry…*, WZ 270 S995c 1791
Condition when received: The cloth-cased book was in poor condition. The glued spine was cracking, sewing was breaking and some pages were detaching. Black mold was present along the gutter on pages 80-90. Bookplate on inside front cover was lifting.
Foldout: An oversized foldout opposite page 230 was detached from the book. It was acidic and folds were weak. In addition, there were several large tears in the foldout that had been mended using scotch tape.
Conservation treatment: The book was surface cleaned using a Hepa vacuum with micro tools. Mold was deactivated (269 pages) using a spray-applied mixture of 20% deionized water with 80% ethyl alcohol (Nasco). The text block was brought into plane using mild pressure. The tape carrier had lost adhesion with age and popped off without resistance. The foldout was submerged in a solution of 1:1 methylene chloride and toluene (Fischer Scientific). As a result, the adhesive was significantly reduced. The pages were submerged in a series of baths using deionized water conditioned to pH 8.5 using a combination of ammonium hydroxide (Nasco) and calcium hydroxide (Nasco). The paper was allowed to dry thoroughly between each of three baths. The third bath was conditioned using only calcium hydroxide. As a result, a minute amount of alkaline reserve (calcium carbonate) was amalgamated and precipitated in the paper. After washing, the paper was lighter in color, stronger, and the acidic content was lower. Foldout tears were mended using tosa tengujo and kizukishi (all papers from Japanese Paper Place) and secured with zin shofu wheat starch paste (BookMakers). Foldout was repositioned opposite page 230 and hinges into gutter using sekishu paper (above). Hinge and bookplate was adhered using the above adhesive.
Conservation carried out by Rachel-Ray Cleveland
NLM Paper Conservator, 01/2007